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JOURNAL

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AMERICAN WELDING SOCIETY
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Annual Meeting

In the March issue of the JOURNAL there is given a tentative program of the Annual Meeting of the American Welding Society. An unusual feature of this program is the fact that three technical sessions have been arranged instead of two as formerly. These sessions cover a variety of subjects of paramount importance to the welding industry. Prepared discussions are being arranged by prominent experts in the several fields of welding. The Meetings and Papers Committee hope that this arrangement will stimulate discussion by all the members.

The annual dinner this year will be held at Keen's English Chop House, and it is to be a stag affair. An extraordinarily good menu has been arranged for this occasion and sixteen vaudeville acts will supply the entertainment feature. There are to be no formal speeches. This dinner is to serve as a means of relaxation from the more formal business and as a medium for becoming acquainted.

Each member and guest attending the dinner will receive a ticket which will be used in drawing a number of prizes that are to be offered.

Building Codes

At a recent meeting of the Executive Committee of the American Welding Society a committee was appointed on "Building Codes." The members of this committee are:

E. A. Doyle, Chairman.
H. H. Moss, Secretary.
F. T. Llewellyn.
E. Von Steeg.

The first meeting of the committee was held on March 9, in which the scope of the committee's activities were discussed in detail.

It was felt that clauses should be inserted in various building codes which would permit the use of welding where it was desirable. The following motion was passed:

That the Chairman prepare and submit for the approval of other members of the Committee, a clause covering the application of welding and cutting in building codes for submittal to the American Welding Society during their April meeting, with a request that it be considered as a standard clause suitable for insertion in State or Municipal Building Codes, and that the Society through its officers, sections, and members, endeavor to have it included in all Building Codes that come to their attention as being produced or revised.

Standard Codes and Procedures

Considerable attention has been given by the Society during the past year as to the necessity for standards in welding, particularly in the matter of nomenclature, definitions and symbols, and also suitable procedure codes for pipe line welding, structural steel and pressure vessel welding.

A committee on nomenclature, definitions and symbols has been at work for some time and has framed tentative recommended nomenclature and symbols, which will be reported very shortly to the Society.

In the matter of standard procedures mentioned above, considerable progress has been made in drawing up rules and regulations for qualifying welders in the pipe line, structural steel and pressure vessels fields.

At the request of the Boiler Code Committee of the American Society of Mechanical Engineers, the Society will appoint a subcommittee to deal with the matter of drawing up a general procedure covering design, technique of welding, selection of materials, apparatus, supervision, inspection, qualification of welders and testing. It is expected that these general rules will be made a part of the Boiler Code for the welding of pressure vessels.

The Engineering Standard Committee has appointed a sectional committee on a code for pressure piping which is being sponsored by the American Society of Mechanical Engineers. A subcommittee has in charge the work covering the welding of hydraulic, water, steam, gas, and refrigeration piping. The American Welding Society has been asked to prepare the first tentative draft of a code on welding for the consideration of this subcommittee.

Considerable progress has also been made by the American Bureau of Welding in drawing up regulations covering inspection and qualification of welders for the structural welding field.

The efforts of the Society in these several directions will do much to standardize procedures in these important fields of welding which will result in considerable economies and sound engineering methods, which will, in turn, result in uniform products which will have the confidence of the public at large.

Foundry Research at Mellon Institute

Announcement has been made by Dr. Edward R. Weidlein, Director, Mellon Institute of Industrial Research, Pittsburgh, Pa., that the Whiting Corporation, Harvey, Ill., has established in the institution an Industrial Fellowship, whose holder, Dr. Edward E. Marbaker, will conduct research on cast iron. The results of these investigations will be published for the general benefit of the foundry industry.

For a number of years the Whiting Corporation has been carrying on a systematic program of development for the purpose of improving equipment and methods for the production of cast iron. It has recently been determined to expand this work and in consequence the Coporation will sustain research at Mellon Institute. Dr. Marbaker, the Whiting Corporation Fellow, will work in close cooperation with the research committee of the American Foundrymen's Association.

Dr. Marbaker has been a Fellow of Mellon Institute since 1921. Previously he was chief chemist for the Westinghouse Lamp Company and for the Cleveland Wire Division of the National Lamp Works of the General Electric Company. He received his professional training at the University of Pennsylvania (B.S., 1910; Ph.D., 1914).

Tests Made of Strength of Welded Structures with View to Reducing Cost of Metal Products*

By H. L. Whittemore†

Welding is coming into extensive use for joining parts of machines and structures which are made of steel or other metals. In many cases, castings are being replaced at lower cost by parts made from rolled steel pieces welded together.

The Bureau of Standards has assisted in the development of welding by testing pressure tanks, plate girders and other welded structures to determine their safety and the behavior of the welds under load.

In 1922-23 we cooperated with the American Bureau of Welding in an investigation of the strength of about 60 welded tanks. As more information is needed to enable the Boiler Code Committee to revise its Safety Code for Unfired Pressure Vessels, another investigation, to cost, it is estimated, $100,000, is contemplated. In addition to strength, impact and fatigue tests of the shells at and near the welds, a breathing test will be necessary. For this unusual test, several tanks will be connected with apparatus which will raise the pressure in the tanks to 50 per cent more than the working pressure, that is, to 375 pounds per square inch, then allow it to drop practically to zero, and repeat this cycle about once each second until either the tank fails or 1,000,000 cycles have been completed.

Enthusiasts on welding are confident that this investigation will prove the superiority of welded tanks over the riveted and brazed tanks and that it is only necessary to demonstrate the safety of welded tanks to have them very widely used. It is estimated that the cost of a welded tank is so much less than other methods of fabrication that there will be an economic saving to the people of this country.

*Reprinted from *The United States Daily*, March 22.

†Chief, Section of Engineering Mechanics Bureau of Standards.

The welding of the steel framework of buildings, the failure of which would endanger life and property, is a development which has been viewed with concern by structural engineers. Several buildings have been welded successfully and it is claimed that in many cases a saving of 20 per cent in steel is effected.

The greatest advantage of welding over riveting in so far as the surrounding community is concerned is that welding is noiseless. When it becomes general there will be no more ear-splitting din from the riveting hammers on adjacent buildings under construction. The Health Departments in some of our larger cities are considering this question seriously at the present time.

Before we go too far, however, welded structures must be proved safe. Our laboratories are cooperating with the American Bureau of Welding in an investigation of the strength and behavior under load of a large number of typical welded joints suitable for use in building. It has been estimated that the cost will approach $200,000. Its importance is shown by the active support of structural engineers in the employ of such large fabricating organizations as the American Bridge Company. Two of the largest steel corporations will donate the steel, and 74 fabricating shops will make the specimens under a carefully worked-out procedure control and inspection. These specimens will be tested in many engineering schools in this country and also here at the Bureau of Standards.

The results will enable city officials and others to approve structures which will be safe and may free this recently developed fabricating process from the severe restrictions to which it has hitherto been subjected. As in the case of welded tanks, the economic saving to this country should be appreciable.

A Week of Welding

Reprinted from March 29, 1928, issue of *Engineering News-Record.*

The biggest week to date in the field of structural welding has just been recorded. Two large and noteworthy structures were completed, a factory in Philadelphia and a through-truss railroad bridge at Chicopee Falls, Mass. Both involved significant progress in the art, moreover. The details were worked out with a skill far ahead of that heretofore shown in welded structures, and their application by due combination of shop and field welding revealed the thoroughly practical thinking that is being brought to bear on the problem at the present time. In the light of these performances it is fair to look forward to a steadily and rapidly extending field. Already plans are well advanced for the use of welding in several high city buildings, and the adjustment of building codes to the new art is progressing. In all this growth the essential place of welding as a companion to riveting for the joining of structural steel parts is progressively working itself out.

Learning by Errors

Reprinted from March 29, 1928, issue of *Engineering News-Record.*

An incidental point of much value was brought out by the Chicopee Falls bridge. Rarely do engineers, or members of other professions for that matter, admit in public that their work on any of their undertakings was not wholly perfect. Papers read before technical societies are apt to relate that the work under discussion went forward with clocklike regularity along the lines laid down in advance, by virtue of faultless planning and supervision. It is refreshing, then, to hear some one frankly admit, as did Gilbert D. Fish last week in describing the Chicopee Falls work at a society meeting, that many of his carefully worked-out details of design had been found unsuitable under practical conditions and would be changed if the work were to be repeated. One might expect, of course, that many mistakes would be made in a relatively new field like that of the application of welding to structural steel construction, but it is also true that mistakes are made in all fields of engineering. There is no good reason for concealing any of them, but false pride keeps many of us from doing so. To pass on to our fellow engineers through articles or papers the benefit of experience gained through our successes alone is to give but half, and in some ways the poorer half.

SECTION ACTIVITIES

Chicago

On April 6, the Chicago Section held a very interesting meeting. Two splendid reels of motion pictures, entitled "Cuba the Island of Sugar," were shown. The speaker of the evening was Mr. T. H. Hamer of the Air Reduction Company. His subject was "Factors Involved in Economic Gas Cutting."

On May 4 another meeting of this Section will be held and it will be an open discussion of welding and cutting in the heating and plumbing industries. This will be preceded by moving pictures entitled "King of the Rails"—three reels, from the General Electric Company. This discussion is the first open meeting which will be held this year.

Los Angeles

The Los Angeles Section held its March meeting on the 29th. The main topic of this meeting was "The Welding of Household Piping." A film was also shown which was very interesting.

Pittsburgh

A very successful meeting of this Section was held on March 28th. Mr. G. A. Hughes spoke on "Spot Welding."

Western New York

The regular monthly meeting of the Western New York Section was held at 8:00 p. m., March 23. This was a joint meeting with the American Institute of Electrical Engineers and the Engineering Society of Buffalo, the attendance being about 500. Mr. John B. Taylor, consulting engineer, of the General Electric Company, spoke on the subject of "Making Sound Visible and Light Audible." The lecture was found extremely interesting and instructive, being illustrated by numerous lantern slides showing and explaining to the audience the entire story of the recording and reproduction of sound, from the very beginning of this wonderful discovery, up to and including the demonstrations of listening to the sound of light and seeing the transmission (through the air) of music.

A small incandescent electric light bulb was used to demonstrate the sound of light, Mr. Taylor showing how the amount of sound could be reduced or increased by a slight movement of the bulb, and when using a Neon bulb, a simple turning of the bulb would emit various degrees of sound.

Mr. Taylor also demonstrated the transmission of music along a beam of light, then allowing the audience to interrupt the music by placing their hands across the beam of light.

It was one of the most interesting and instructive meetings recently held.

Philadelphia

On April 16th the Philadelphia Section will hold its regular monthly meeting in the Auditorium of the Engineers Club, 1317 Spruce Street. Mr. W. M. Dunlap, of the Aluminum Company of America, will talk on "Welding of Aluminum." This is a very interesting subject and all welding foremen and welding supervisors who are interested in the art of welding are invited to attend.

The March meeting of the Philadelphia Section was held on the 19th and was devoted to the subject of Structural Steel Welding. Prof. F. P. McKibben, consulting engineer of the General Electric Company, presented a paper describing in detail the application of welding to the construction of a large factory building of the General Electric Company in Philadelphia. Prof. McKibben illustrated the method used to design welded girders as compared with riveted structures, and also reviewed the theoretical considerations of the applicability of welding in this field. He was followed by Mr. Gilbert D. Fish, who described the welding of the Chicopee Falls railroad bridge. This is one of the first all-welded bridges of importance and represented a number of novel features of design. He demonstrated quite clearly the need of cooperation between the structural steel engineer

and the welding engineer to affect the greatest economies and advantages from the use of welding.

Mr. W. Spraragen, technical secretary of the American Welding Society, presented a brief review of some of the activities of the Society, and particularly its research work on welding of structural steel, pressure vessels, welding wire, effect of heat of welding on adjacent metal, study of welds at elevated temperatures, etc. A large audience was present at the presentation of these papers and considerable discussion followed.

New York

One of the most successful meetings of the season was held on March 21st as a joint meeting with the local section of the American Society of Civil Engineers. About 350 people interested in the subject of structural steel welding were present, and discussion was quite spirited. The rapid application of welding in this field was particularly stressed. Two addresses were delivered; one by Mr. Gilbert D. Fish, consulting engineer of The Westinghouse Electric & Manufacturing Company, on "Arc Welded Plates and Bridges." The subject matter covered types of structural joints, basic design calculations for structural arc welds and construction methods used on two buildings and three bridges. The lecture was illustrated by lantern slides.

The other paper was presented by Mr. C. A. Daley, maintenance of way engineer of the Air Reduction Sales Company, on "Oxy-Acetylene Practices of Interest to Civil Engineers." Special reference was given to building up rail ends, repair of frogs and switches, welding of powerplant pipes, replacement of bridge members, maintenance of bridges and excavating machinery, etc., demolition of bridges and steel structures.

EMPLOYMENT SERVICE BULLETIN

Opportunities.—The Society is glad to learn of desirable opportunities from responsible sources, announcements of which will be published without charge in the BULLETIN.

Services Available.—Under this heading brief announcements (not more than seventy-five words in length) will be published without charge to members. Announcements will not be repeated except upon request received after an interval of three months; during this period, names and records will remain in the office reference files.

Note.—Copy for publication in the BULLETIN should reach the Society's Office not later than the thirtieth of the month if publication in the following issue is desired. *ALL REPLIES should be addressed to the number indicated in each case and mailed to Society headquarters.*

POSITIONS VACANT

V-42. Experienced Gas and Electric Welder wanted who is capable of taking charge of department in a production shop. Must be practical welder as well as a good supervisor.

V-43. Need structural steel arc welder. Give experience, age and salary desired.

SERVICES AVAILABLE

A-71. Welding supervisor desires position. Have had considerable experience in this capacity and also salesman.

A-72. Certified welder desires position. Have had five years' experience as electric welder in shop and field. Desire position in or out of town.

A-73. Electric arc welder desires position. Have had four years of all around experience with the Westinghouse Electric & Manufacturing Company.

A-74. Welder desires position. Have had four years' experience with the SOS Welding Corporation.

Arc Welded Steel Frame for Building at General Electric Company's West Philadelphia Works*

By FRANK P. MCKIBBEN†

Progress in Structural Engineering

MAN progresses slowly. But, he progresses. His efforts as exhibited in the structural field during the last half century may be thus summarized:

First: The decade between 1880 and 1890 heard much discussion among American engineers concerning the relative merits of pin-connected and riveted trusses, but by the latter date it was conceded that the riveted truss for most, but not all, uses was superior. And the pin-connected truss which had been the standard in America surrendered its prestige to the European riveted type.

Second: By 1900 the riveted steel frame for tall buildings was no longer a curiosity. It was a standard construction of recognized merit.

Third: The decade ending 1905 witnessed the remarkable increase in the use of concrete for structural building purposes. Many concrete buildings and some concrete bridges collapsed during those early days, but man progressed. Concrete buildings and bridges had come to stay—to fill a desideratum.

Fourth: Considére's classic experiments on spirally reinforced columns resulted in a great step forward in the use of stronger columns so that by 1910 or thereabouts we were erecting large reinforced concrete buildings characterized by flat slabs, then an innovation, and by spirally reinforced columns.

Fifth: And now we are witnessing another transition stage wherein welded steel structures are creeping into the structural field at first by such gradual steps as to be almost imperceptible; but now the movement is going forward by leaps and bounds. Welded steel frames possess some good distinctive characteristics, and will without doubt find an appropriate place in a structural fabric consisting of the useful elements of pins, rivets, reinforced concrete, welded joints.

As engineers it's our task to allocate each type to its proper and useful sphere. In 1877 the first public demonstration of welding steel by the electric arc was shown in an experiment before the Franklin Institute in Philadelphia. And it is somewhat fitting that I should describe the first electrically welded steel building erected in Philadelphia at the close of 1927 and the beginning of 1928.

---

*Presented before meeting Philadelphia Section, A. W. S., March 19, 1928.
†Consulting Engineer, General Electric Company.

The Use of Welding in Structures

Since about 1915 somewhat over thirty-five steel building frames have been fabricated by welding; twenty-five miscellaneous structures, including large gas or oil tanks, towers, and such important constructions as plate girder and truss bridges, have been entirely built new as welded structures or have been extensively strengthened or modified by this process; and approximately fifteen ships and barges have been welded throughout.

The Latin expression, *Festina lente*, meaning make haste slowly, surely is suitable as a motto for the conservative and careful engineer, but the array of welded structures included in the above mentioned list of about seventy-five examples is sufficient evidence that welding has well passed the experimental stage and established its place in the family of useful

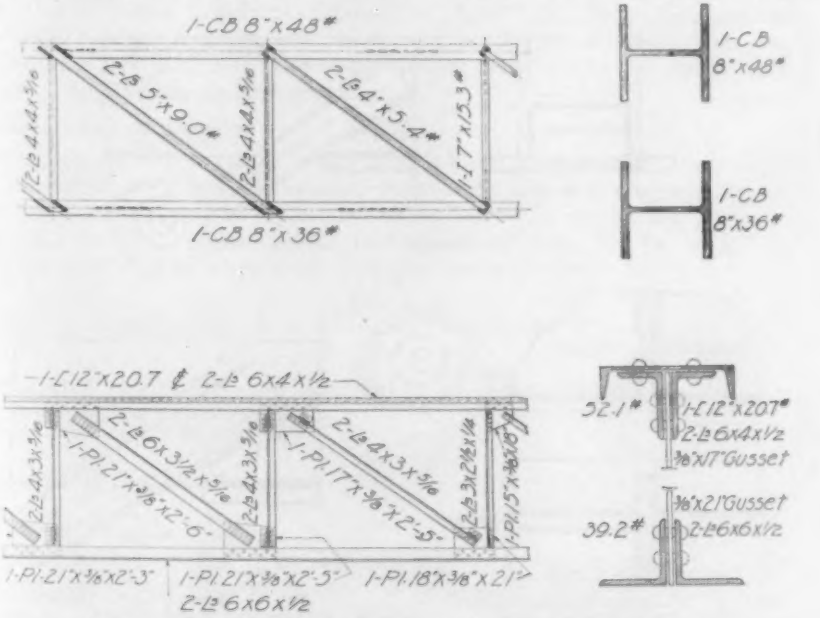


FIG. 1. COMPARATIVE DESIGN OF WELDED AND RIVETED TRUSS

tools. We must not be so conservative as to lean backward and make no progress at all. It is our concern to see that the use of welding in bridges and buildings is confined to responsible designers, fabricators and engineers who will apply it to that field for which it has well defined advantages over any other known method of building, and to exclude it where not suitable.

Some Problems To Be Solved

I am no longer concerned about the safety or desirability of carefully designed welded structures properly built. In many cases they distinctly lower the cost of construction; the noiseless welding process commends itself alike for structures being built in close proximity to hotels and

hospitals, and to office buildings as well, in fact in any thickly settled community; the elimination of unnecessary gusset plates is noteworthy; economies resulting from absence of holes in tension members are worthwhile; oftentimes considerable time may be saved in making drawings; the very great reduction in number of templets at the fabricating shop is marked.

Naturally, several unsolved problems appear. That's wherein lies the fun. Among these are:

1. Revision of building codes in those cities where no provision is made for welding. Such codes do not specifically exclude welding, but they do not specifically include it, because it's new. Building codes should be revised to include the issue of permits by responsible municipal bureau heads to responsible fabricators.

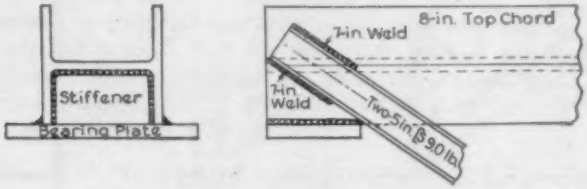


FIG. 2. METHOD OF LOCATING WELD

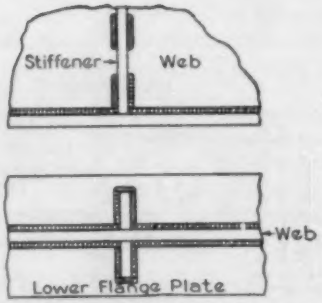


FIG. 3. WELDING STIFFENER TO WEB AND LOWER FLANGE

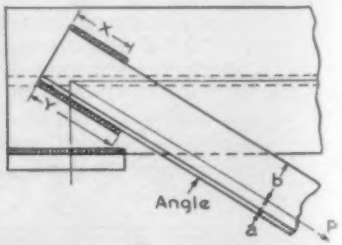


FIG. 4. DETERMINING LENGTH OF WELD FILLET

2. Another interesting need is a simple practical series of accomplishment tests for employing welders on important works. I have had the welding inspector test applicants seeking work, by watching their proficiency in maintaining a steady arc of proper length, in depositing a fillet on vertical as well as horizontal surfaces, in making a fillet of specified length, in securing proper penetration on each of two plates welded together. This last can be easily tested by arranging the plates in such a manner as to be wedged apart, thus breaking the fillet.

This problem is being studied by a committee.

3. More extensive use of jigs in fabricating shops is necessary to reduce cost of assembling. The efficiency of jigs was shown to a marked

degree in assembling the small triangular skylight truss frames of General Electric Company's West Philadelphia building No. 1. The saving in unit cost is great where a large number of similar objects are to be made. In other words, the use of jigs eliminates templets and results in further saving of assembling costs.

4. Authentic welding machines which deposit continuous or intermittent fillets offer great opportunities for securing cost reduction and better welds. For example, machines which weld simultaneously the flange on both sides of a plate girder web give more uniform quality of fillets, more speed and lower costs than manual welding. And because automatic machines use continuous wires for electrodes the time and wire lost in the frequent changing of hand welding are eliminated.

5. Standardization of details such as connections of one beam to another, or of beams to columns is needed. And if this be worked out now while the welding program is just starting much time will be saved. Such connections are very different from similar ones in riveted construction. Work is being done on this problem.

Some Details of Design

Example A. Given a roof truss, Fig. 1, having a top chord made of one 8″ H section with web horizontal, proportion the end diagonal, A, and welding connecting it to top chord, using 16,000 lb. sq. in. for tension in diagonal and 3000 lb. per linear inch shearing value for ⅜″ x ⅜″ triangular fillets. The truss is symmetrical about center.

$$\text{Tension in end diagonal} = \frac{47{,}500 \times 12}{7} = 81{,}400 \text{ lb.}$$

$$\text{Net area required in end diagonal} = \frac{81{,}400}{16{,}000} = 5.1 \text{ sq. in.}$$

Use 2-5″ ['s 9.0 lb. = 5.26 sq. in.

$$\text{Length of } \tfrac{3}{8}\text{″ fillet required} = \frac{81{,}400}{3000} = 27.1\text{″}$$; use 4 fillets each 7″ long, Fig. 2.

The 7″ fillet of Fig. 2 would ordinarily be indicated on the detail drawing as 7 W if it be shop, and 7 F W if field welded.

Example B. Given a welded plate girder, span 40′ c. to c.; uniform load of 4000 lb. per linear foot over entire span; assuming web 40″ x 5/16″ proportion tension flange using 16,000 lb. sq. in.

$$\text{Maximum moment at center} = \frac{4000}{8}(40^2)12 = 9{,}600{,}000 \text{ in.-lb.}$$

$$\text{Required net area in tension} = \frac{9{,}600{,}000}{40(16{,}000)} - 1/6\ 5/16\ 40$$

$= 15.0 - 2.1 = 12.9$ sq. in.

Use one plate 16″ x 13/16″, or two plates to give the same area.

Notice that this simple calculation for tension flange reveals a double saving, first, in that no allowance need be made for rivet holes; and, second, that as no vertical row of holes is punched in the web the web

equivalent for the welded girder is larger, and the flange correspondingly smaller than in the riveted girder. In many girders, however, the greatest saving can be secured in using as stiffeners single flat bars with one edge welded directly to web, thus eliminating not only fillers but also those legs of angle stiffeners which lie parallel with the web, Fig. 3.

Example C. Given a single angle in direct stress such as tension, to find the proper lengths of fillets to connect the angle to connecting piece; using tension at S lb. sq. in., and longitudinal shear on fillet at f lb. per linear inch. Fig. 4.

Using .6 as a factor to allow for eccentric loading the required area of one angle $= \frac{P}{.6S}$ where P = pull in angle, and S = allowable unit tension. Then by taking moments about outer edge of angle leg the length of fillet required along back of angle $= Y = \frac{P\,b}{(a+b)f}$; and the length x for the fillet along outer edge of leg is $\frac{P\,a}{(a+b)f}$. Naturally, these added make $\frac{P}{f}$ as they should.

GENERAL DESCRIPTION OF GENERAL ELECTRIC COMPANY'S BUILDING NO. 1, WEST PHILADELPHIA, PA.

Although Building No. 1, now being completed at the General Electric Company's West Philadelphia works at 69th Street and Elmwood Avenue, is first in number, it is not first in order of construction, as several other buildings have been in use for some time. This latest structure,

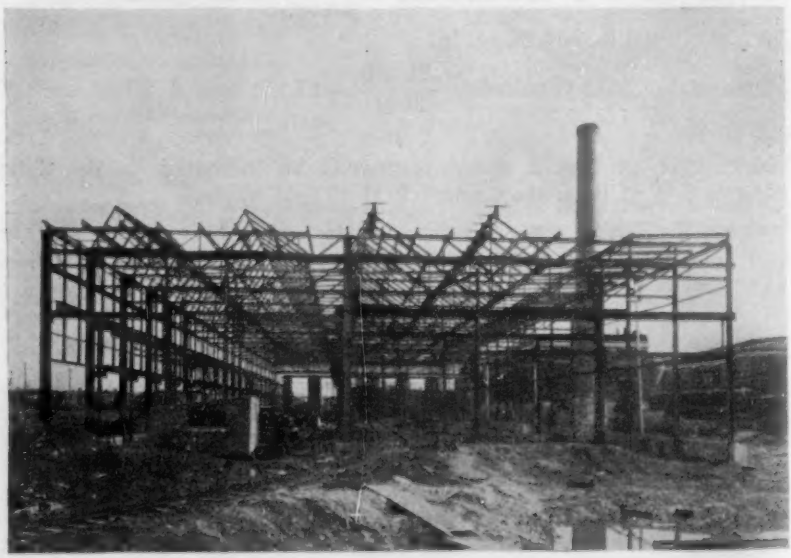


FIG. 5. END VIEW OF COMPLETED STEEL FRAME

differing from the others in that its steel frame is arc welded, consists of a head house or transept parallel with Elmwood Avenue and two main aisles at right angles thereto. The head house is 78′ wide and 171′ long with vertical clearance of 43′. One aisle is 59′ wide and 474′ long with vertical clearance of 34′ from ground floor to lower chords of roof trusses, while the other aisle is 79′ wide and 474′ long with a reinforced concrete gallery floor, in all but the two westerly bays, nearly midway between the ground floor level and the lower chords of trusses. To be exact, the gallery floor is 20′ above the ground floor, and is connected with a similar gallery in existing Building No. 4 by an enclosed passageway. These aisles and the head house comprise a building approximately 138′ wide by 552′ long with total ground area of 80,150 sq. ft.

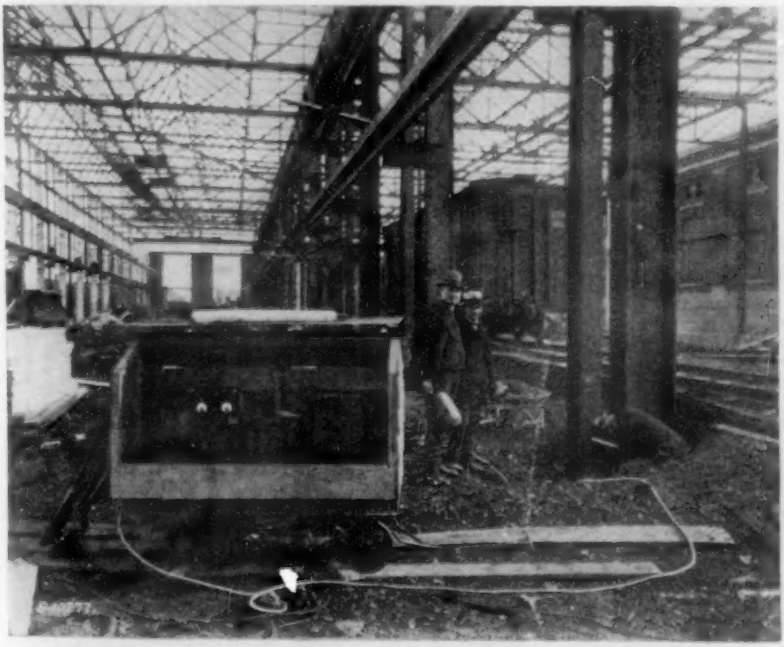


Fig. 6. View of Center Row of Columns and Welding Machine

When completed the building will be used for the manufacture of arc welded steel tanks of various kinds and sizes.

Concrete spread footings in clayey soil serve as foundations for brick walls, steel columns and for the reinforced concrete columns supporting the gallery. The ground floor throughout consists of a wooden block surface on a concrete base on cinder fill, and the gallery floor is also wooden block on flat slab construction. Outside walls are of brick; and the roof gypsum slab cast in place. The building will be well provided with natural light from unusually large windows in all external walls, and from four lines of sawtooth skylights—two lines in each main aisle.

Steel Framing

The steel frame consists of steel columns, made of new Carnegie beam types, between which are welded transverse trusses of the Pratt type with parallel chords in the two main aisles, but with inclined top chords in the head house trusses. The latter trusses have spans c. to c. of columns of about 77′, and vary in depth from 8′ 4″ at one end to 6′ 4″ at the other to carry the sloping roof of the head house. One main aisle has roof trusses 7′ deep with 6 panels each 9′ 9″, making the span 58′ 6″. The other main aisle has 78′ trusses 7′ deep with 8 panels at 9′ 9″. As all truss chords in the main aisles are horizontal and as the main purlins rest on the top chords of these trusses, roof slopes for drainage are provided for by sloping the secondary purlins.

FIG. 7. INTERIOR OF NORTHERLY AISLE. AT TOP OF PICTURE MAY BE SEEN THE WELDED TRUSS AT INTERSECTION OF NORTH AISLE AND HEAD-HOUSE, CARRYING CRANE, ROOF, CLERE-STORY AND ONE END OF 77′ ROOF TRUSS IN HEAD-HOUSE

The following data show the very considerable amount of saving in weight of steel resulting from the use of welded in place of riveted trusses: for 78′ span, estimated weights of welded and riveted trusses were 9200 lb. and 13,200 lb. respectively, a saving of 4000 lb. or 43 per cent of the welded truss; for 58′ 6″ span estimated weights of welded and riveted trusses were 5000 lb. and 6800 lb. respectively, a saving of 1800 lb. or 36 per cent of the welded truss.

In general each column had a 1½″ cap plate welded directly to its web and flanges, but the 1½″ base plate was in most cases not welded to the column. Each anchor bolt was connected to each column by passing

between the column flange and a short angle standing vertically with outer edges of both legs welded to the face of column flange. The anchor bolt nut bears against a plate washer resting on upper end of the angle. The device is very simple. Fig. 8.

The bays in main aisle were 24′ to 25′ while those in the head house were from 25′ 7″ to 29′ 3″.

The design of roof trusses is characterized by the use of one 8″ Carnegie beam for each top and bottom chord with flanges vertical; to the outer surfaces of which are welded channel diagonals and to inner surfaces 7″

FIG. 8. DETAIL OF ANCHORAGE FOR STEEL COLUMNS

I beam verticals. Fig. 1. By thus welding diagonals and verticals directly to chord flanges the use of over 1200 gusset plates were avoided in the trusses. Another feature is the absence of lattice bars, not only in all trusses, but generally throughout the building. In only two members in the entire building were lattice bars used.

The fillet welds, of triangular cross section with base and altitude gen-

erally ⅜″ each, are subjected to a longitudinal shear, and the unit shearing stress used in the design is 3000 lb. per linear inch for ⅜″ fillets. As the critical shearing section for a ⅜″ x ⅜″ triangular fillet is .265″ this corresponds to a shear 11,300 lb. per sq. in. In comparison with many tests made by the General Electric Company this represents a factor of safety of at least four.

A roof load of 60 lb. per sq. ft. was used in the design, divided equally between live and dead, applied not only to the level portions of the roof but also to the sloping surfaces of skylight monitors. Unit stresses in steel members were those of the Philadelphia building code.

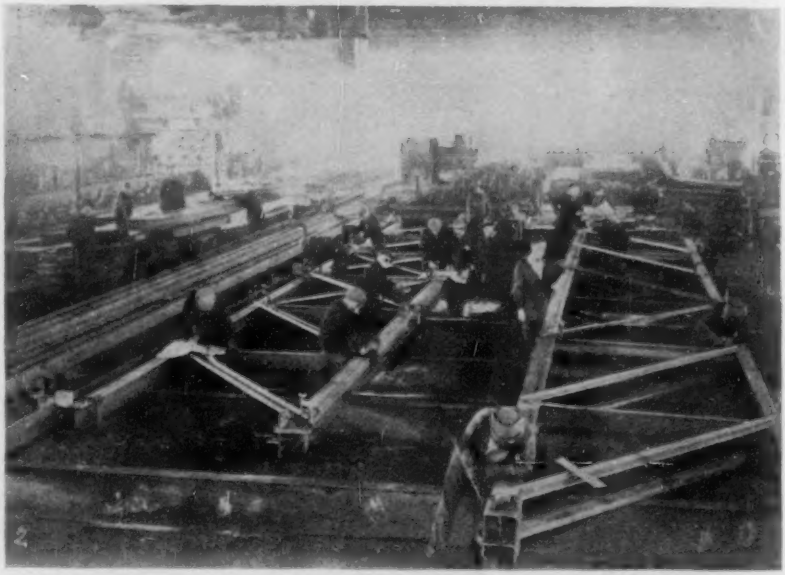


FIG. 9. ROOF TRUSSES IN WELDING FABRICATING SHOPS

Horizontal bracing, consisting of diagonal rods with Carnegie beam struts, is provided in plane of truss lower chords in all bays of the head house and in the 58′ 6″ main aisle where cranes operate, but in the 78′ main aisle with concrete gallery lower chord bracing is used only in four bays. And horizontal top chord bracing is provided in four bays of both main aisles and in two head house bays. Vertical longitudinal bracings were also used in several bays to resist crane stresses.

Cranes

Provisions are made for the following cranes: In the head house 10-ton bridge cranes with span of 73′ 5½″; in the 59′ main aisle 10-ton bridge cranes with spans of 55′ and 2-ton wall cranes on either side; in one end of 79′ aisle one 5-ton bridge crane with span of 46′ 2″. All bridge crane runway girders are Carnegie beams supported generally direct on top of auxiliary crane columns. The only exception is at intersection of head

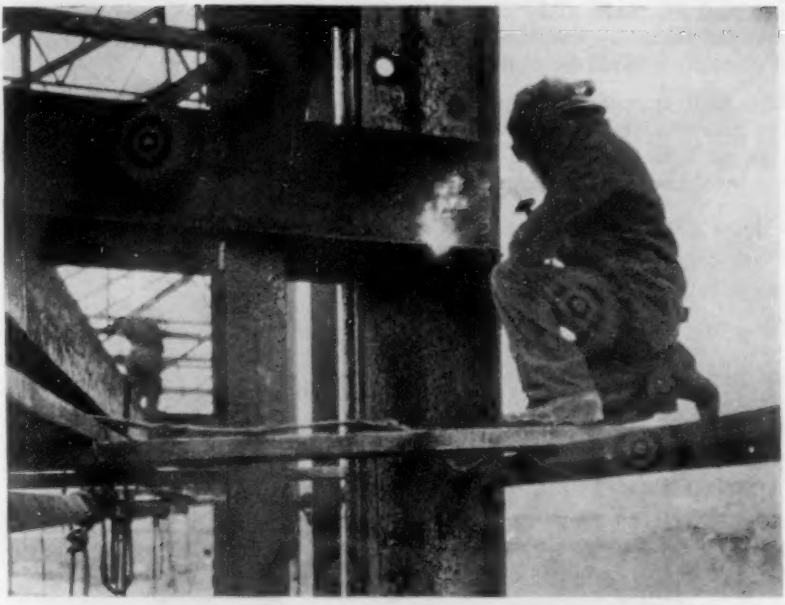


FIG. 10. BRACKET SUPPORTING WALL CRANES WITH WELDER AT WORK

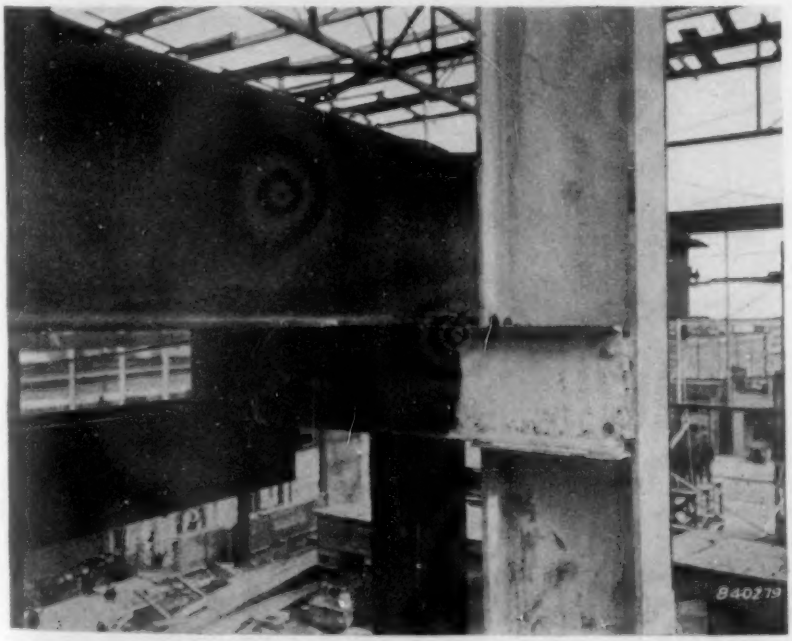


FIG. 11. COMPLETED BRACKET SUPPORTING CRANEWAYS SHOWING WELDING AND ERECTION BOLTS

house and 59′ main aisle where the 10-ton head house crane girders are supported on a deep welded truss carrying not only the crane, but roof and clerestory loads as well.

The wall cranes are supported on brackets carried by the auxiliary crane columns and main columns. And as these cranes exert horizontal forces at both upper and lower levels as well as vertical forces at the lower level their runway supports are not simple.

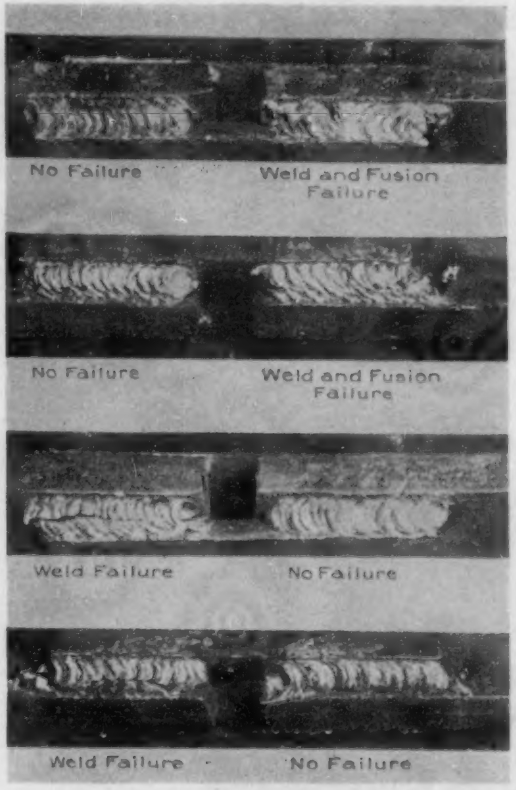


FIG. 12. TENSION TEST SPECIMEN 3A MADE BY WELDER NO. 3. APPROX. ⅝″ x 2½″ FILLET. ULTIMATE LOAD 13,267 LB. PER LINEAR INCH OF WELD

In the head house are three interesting structural features; first, supporting one transverse head house 77-ft. truss on two longitudinal wall trusses at connection with this new building to an existing adjacent one; second, supporting one end of one transverse head house 77-ft. truss at the center of a 58′ 6″ truss at intersection of head house and one main aisle; third, supporting head house crane runway girders by welding them to cantilever ends of two needle beams supported by 58′ 6″ trusses at intersection of head house with main aisle.

Welding

The use of welding resulted in a considerable saving of steel, in a reduction of cost of the steel frame, in the elimination of noise due to riveting, and in promoting the electrical industry. Having a total of 989 tons of steel, of which 745 tons passed through the welding shop of the American Bridge Company at Trenton, N. J., this building is one of the heaviest among welded structures. It is also unique in that it exceeds all other welded buildings in the use of trusses.

At the Trenton fabricating shop five welders were generally used, each using a single operator motor generator set which consists of a gener-

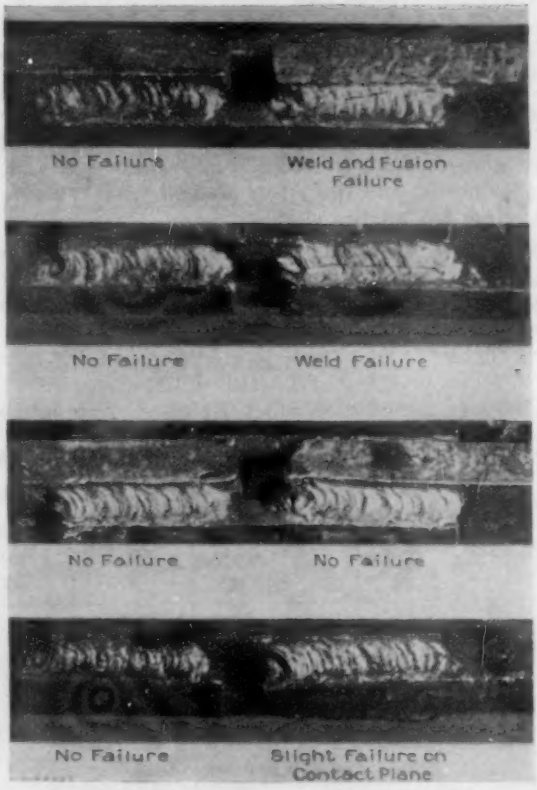


FIG. 13. TENSION TEST SPECIMEN 3B MADE BY WELDER 3. APPROX. ¾″ x 2⅛″ FILLET. ULTIMATE LOAD 12,070 LB. PER LINEAR INCH OF WELD

ator, control panel, motor, starter and reactor assembled on a base. At the building site in West Philadelphia two welders were used, each supplied with a machine brought from Trenton and made portable by mounting on simple hand trucks.

When depositing a ⅜″ x ⅜″ triangular fillet the arc voltage was about 23 to 25, and amperes 175 for 3/16″ welding electrode. Direct

current was used and was subject to control by the operator, the current being changed by shifting the brushes, low voltage for light work and higher voltages for heavy work.

In the fabricating shop a series of 18″ I beams from 21′ to 24′ long were supported about 9′ apart on the shop floor, and connected together with a steel bar welded to each beam. The positive terminal was bolted to the web of one of these beams, and the negative connected to the 3/16″ x 24″ electrode in the electrode holder held in operator's hand. (Fig. 9).

The 206 skylight trusses were nearly alike and were assembled by clamping the members in jigs, which expedited the process greatly. Jigs for small triangular trusses can be made by welding flat plates to skids, then welding small angle clips to the plates so that when the truss members are laid against the clips the truss is quickly assembled and clamped, then either welded in place or removed for welding.

The large trusses were put together by first laying the bottom chord against a long 8″ x 8″ angle welded to the I beam skids, then the top chord spaced and clamped to skids; finally verticals and diagonals were clamped to the chords, and the joints welded. All trusses were assembled and welded lying flat on the skids.

All lengths of welds specified on drawings were marked on the assembled steel and it is interesting to compare the lengths of fillet welds on web members specified on drawings of one of the trusses, T 14, in the 78′ aisle, with actual measured lengths of welds on the truss. Results are shown in Table 1:

TABLE I

Comparison Between Lengths of Fillet Welds on Web Members Specified on Drawing and Actual Measured Lengths of Fillet Welds on Arc-Welded Truss T 14, General Electric Company's Building No. 1, West Philadelphia Works. Dec. 29, 1927

INCHES

Truss	Upper End		Lower End		Total Both Ends	
Member	Drawing	Truss	Drawing	Truss	Drawing	Truss
V_0L_1	30	33¼	30	31½	60	64¾
V_1L_2	30	32¼	30	34	60	66¼
V_2L_3	18	20¾	18	21½	36	42¼
V_3L_4	6	8½	6	7¼	12	15¾
V'_2L_4	6	9¼	6	8¼	12	17½
$V'_2L'_3$	18	21	18	20	36	41
$V'_1L'_2$	30	33	30	32	60	65
$V'_0L'_1$	30	33	30	33	60	66
V_1L_1	20	19¼	20	18½	40	37¾
V_2L_2	20	19½	20	18¼	40	37¾
V_3L_3	13	11½	13	13	26	24½
V_4L_4	13	12	13	12¾	26	24¾
$V'_3L'_3$	13	12	13	12½	26	24½
$V'_2L'_2$	20	18	20	18½	40	36½
$V'_1L'_1$	20	18½	20	18¾	40	37¼
V_4L_5	6	10	6	8¼	12	18¼
$V_4L'_3$	6	6¾	6	6¾	12	13½
Total					598	633¼

1. Total length of actual is 633¼″ compared with 598 specified.

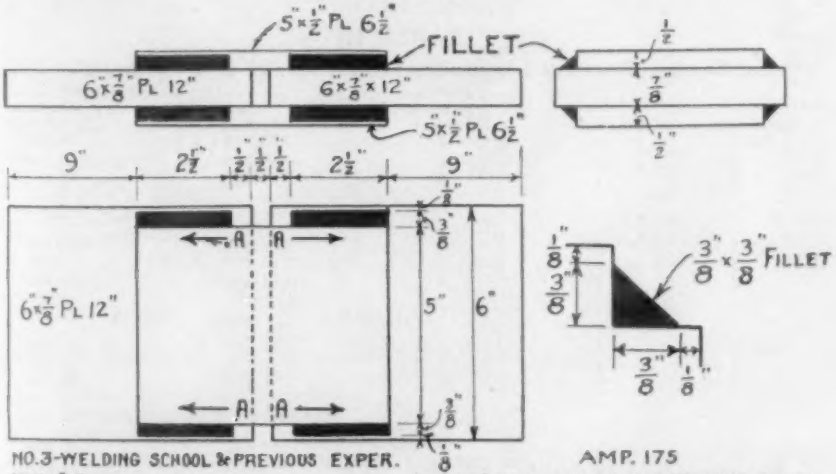
2. Maximum excesses of actual over specified for any one member is 5½″ or 46 per cent of specified weld; and 6¼″ or 52 per cent for another fillet.

3. Maximum deficits of actual as compared with specified for any one member is 1½″ or 6 per cent of specified weld; and 3½″ or 8.8 per cent.

4. Individual fillets may be as much as 10 per cent shorter than specified.

TABLE II

Specimens made at Trenton Plant of American Bridge Co. and tested at Union College.



NO.3-WELDING SCHOOL & PREVIOUS EXPER. AMP. 175
NOS.1&5 " " NO " " NOS.2&4 NO SCHOOL, BUT PREVIOUS EXPER.

NUMBER OF SPECIMEN	WELDER'S NUMER	LENGTH OF FILLETS. TOTAL INCHES	ULTIMATE LOAD POUNDS	ULTIMATE PER LINEAR INCH POUNDS	AVERAGE PER LINEAR INCH POUNDS
3A	3	10	132670	13267	
3B	3	10	120700	12070	12669
1A	1	10	127850	12785	
1B	1	10	120630	12063	12424
2A	2	10	120570	12057	
2B	2	10	113930	11393	11725
4A	4	10	115510	11551	
4B	4	10	111580	11158	11355
5A	5	10	105660	10566	
5B	5	10	101370	10137	10352
			AVERAGE	11705	

All of which shows inspection necessary, but that maximum deficits are not sufficient to appreciably reduce the factor of safety.

It is probable that in truss work costs can be materially reduced by the use of jigs for rapid assembling of truss members, and by specifying on the drawings actual rather than imaginary working points.

The shop fabrication and field erection required nearly two months each for this West Philadelphia building No. 1.

Tests

The design of this building was based in part upon tests made by Rensselaer Polytechnic Institute for the General Electric Company. The plates were of such sizes and thicknesses that at the ultimate loads the

TABLE III

Typical Tension Tests for Longitudinal Shear on ⅜" x ⅜" Triangular Fillets

Specimen	Number	*Fillets* Length Inches	*Ultimate Strength* Total Pounds	Pounds per Linear Inch
8A-1	4	3	173,300	14,420
2	4	3	164,100	13,700
3	4	3	154,400	12,880
			Average	13,600
9A-1	4	4	212,080	13,290
2	4	4	215,100	13,450
3	4	4	191,600	11,990
			Average	12,900
10A-1	4	5	276,580	13,830
2	4	5	268,300	13,410
3	4	5	262,100	13,110
			Average	13,420
11A-1	4	6	317,000	13,210
2	4	6	316,900	13,210
3	4	6	330,300	13,750
			Average	13,390

TABLE IV

Test of Welded Truss for General Electric Company

Total Loads on Truss			Central Deflections	
Panel 1, Lb.	Panel 2, Lb.	Panel 3, Lb.	Loads Increasing, In.	Loads Decreasing, In.
4,050	4,050	3,430	0.00	0.00
7,850	7,850	7,230	0.11	0.10
11,650	11,650	11,030	0.20	0.20
15,450	15,450	14,830	0.31	0.30
19,610	19,610	18,990	0.41	0.41
23,770	23,770	23,150	0.52	0.52
28,260	28,260	27,500	0.67	0.66
32,750	32,750	32,970	0.78	0.78
35,000	35,000	35,220	0.89	0.89

This test was conducted at Trenton, N. J., plant of American Bridge Company.

The loads for zero deflection include the weights of truss, purlins, bracing, and necessary supports for applying live load to purlins.

The design load for panels 1, 2 and 3 is 22,000 lb. (60 lb. per sq. ft. of roof).

TABLE V

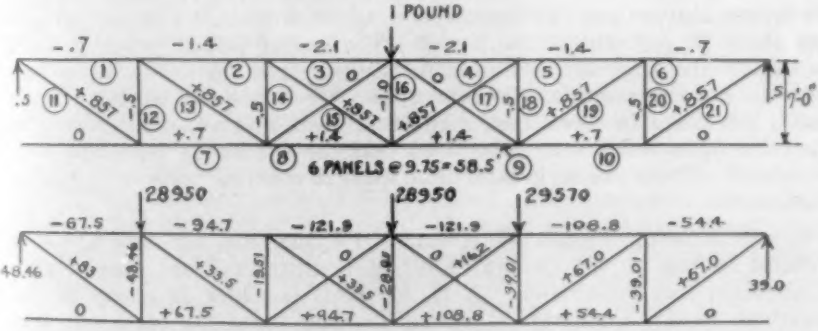
Calculated Central Deflection for Truss = $\sum \frac{STL}{AE}$

Bar No.	S Kips	T Lb.	L Feet	A Sq. In.	STL / A
1	67.5	.70	9.75	9.1	50.6
2	94.7	1.40	9.75	9.1	142.0
3	121.9	2.10	9.75	9.1	274.0
4	121.9	2.10	9.75	9.1	274.0
5	108.8	1.40	9.75	9.1	163.0
6	54.4	.70	9.75	9.1	40.7
7	67.5	.70	9.75	7.06	65.2
8	94.7	1.40	9.75	7.06	183.0
9	108.8	1.40	9.75	7.06	210.0
10	54.4	.70	9.75	7.06	52.5
11	83.0	.86	12.0	5.26	162.9
12	48.5	.50	7.0	4.80	35.4
13	33.5	.86	12.0	2.38	145.2
14	19.5	.50	7.0	4.43	15.4
15	33.5	.86	12.0	2.38	145.2
16	29.0	1.00	7.0	4.43	45.8
17	16.2	.86	12.0	2.38	70.3
18	39.0	.50	7.0	4.43	30.8
19	67.0	.86	12.0	4.24	163.2
20	39.0	.50	7.0	4.43	30.8
21	67.0	.86	12.0	5.26	131.1

$$\sum \frac{STL}{A} = 2431.1$$

$$\text{Central Deflection} = \sum \frac{STL}{AE} = \frac{1000 \times 12 \times 2431.1}{30{,}000{,}000} = 0.97 \text{ in.}$$

S = Stress due to loads on truss.
L = Length of truss member.
T = Stress due to load of unity at center.
A = Gross cross sectional area of truss member.
E = Modulus of elasticity.



stresses in the plates were much below the elastic limit. For specimens in tension the ⅜″ x ⅜″ triangular fillets of varying lengths gave an average longitudinal shearing strength of 13,300 lb. per linear inch of fillet. Whereas, compression specimens with varying lengths of ⅜″ x

3/8" fillets gave from 17,800 to 15,800 lb. ultimate shearing strength per linear inch of fillet.

It is apparent that the 3000 lb. per linear inch used in design for this building gives ample security.

At Trenton three 58′ 6″ trusses were temporarily erected for testing, being supported and braced and erected in the same relative positions that they were to occupy finally in the completed structure. Test loads consisting of I beams were then applied to the top chord joints through purlins until the center truss carried a total load equivalent to 1½ times the load for which it was designed. As the total design dead load was 30 lb. per horizontal sq. ft. and the live the same amount, this test load was equivalent to the full dead plus twice the live load.

The vertical deflection at center top chord joint checked very closely with the calculated deflection. Deflections were observed, Table 4, till the truss was carrying the design load when the central deflection was 0.52 of an inch, then continued till the truss supported the design dead load plus double the design live load, at which time the deflection reached 0.78 of an inch. As the loads were removed the deflections decrements were almost exactly equal to the increments under increasing loads. Till finally upon removal of all applied loads the truss occupied exactly its initial position, showing that no slipping in joints took place under the test. Calculations for central deflections are shown in Table 5.

Before any welder was allowed to do work on this building either at the fabricating shop or the building site, he was given certain tests by a capable welding inspector and his work was subsequently watched by the inspector. A comparison in accomplishment was secured at Trenton by having each of the five welders make two test pieces consisting of two 6″ x 7/8″ main plates spliced by two 5″ x ½″ plates with 10″ of 3/8″ x 3/8″ fillets on each side of the splice. These 10 specimens were then tested, Table 2, and showed that, while the two specimens made by any individual welder showed remarkably close results, the variation between the lowest average and the highest, i. e., between poorest and best welder, was about 22 per cent of the lowest. The lowest values, however, were practically the same as those used in design. It is the lowest value that controls, not the average. Of course, two specimens per welder are not many, but taken in connection with other tests and accomplishments of these five shop welders it is believed that the specimens represent shop variations. These are no greater than exist in concrete tests or in riveted joint tests.

For the building, Harris and Richards, Philadelphia, are the architects. William Dalton of the General Electric Company's Plant Engineering Department has supervision. J. H. Edwards is Chief Engineer of the American Bridge Company, at whose Trenton Plant the steel was fabricated, and who erected the steel. The United Gas Improvement Contracting Company is general contractor for the building other than the steel.

40-Car Garage Fabricated From Scrap Steel By Arc Welding*

By A. VOGEL†

UTILIZING structural steel that would otherwise have been scrapped, the Dallas Power & Light Company has erected, at Dallas, Tex., a 40-car welded garage for the protection of employees' cars, at a total cost of but 25 per cent of the lowest contract price for an equivalent riveted structure. A single portable welding equipment was all that was necessary to do the work.

The garage is made of a steel angle-iron framework covered with corrugated galvanized iron. There are two units, each 16 by 140 feet, divided into ten spans each 14 feet wide, and each unit being capable of covering 20 cars. The units face each other with a 22-foot driveway between.

The steel used in the framework of the garage was salvaged from the framework of an outdoor switching structure which became obsolete with the addition of generating equipment to the power plant. The varying lengths of the steel members removed from this structure, together with the numerous holes already punched for the switching structure (which would have interfered with the punching of new holes to fit the garage structure) would have made it necessary to splice or junk the greater part of the steel if a type of construction other than welding had been used. As the company possessed a portable arc welder, it was decided to fabricate the structure by welding.

The roof trusses are of the simple Fink type. The upper and lower chords are made of two 2 in. by 2 in. angles welded together back to back. The other members of the trusses are made of 1 in. by 1 in. angles. All members of the trusses are tied together with $\frac{3}{8}$ in. plate and the trusses are tied to the columns in a similar manner. The span of each truss is 16 ft. and the height of the center is 3 ft. 2 in. The purlins for the roof are 2-in. angles, with one edge welded to the truss. This leaves a flat side of the angle for the corrugated iron roof to rest on. The columns are made of 5-in. angles. These columns are welded to the plate at each end of the truss. The back columns are braced along the run and to the truss with short knee braces. The columns are spaced on 14-ft. centers. The angles to which the corrugated iron walls are fastened are welded on, the same as the purlins. All welds were of the strap and butt type. The columns are fastened to the wood foundation by means of lag screws through angle clips welded to the base of the columns, and these are the only bolts in the entire structure. The roof and walls are made of 29 gage corrugated galvanized iron roofing fastened on with 6-in. lead head roofing nails.

*Presented as discussion paper on welded building, by Prof. F. P. McKibben.
†Engineer, General Electric Co., Schenectady, N. Y.

Building Up Battered Rail Ends, by the Arc*

By MERRILL H. TURNER†

TO you gentlemen it is not necessary to mention the economies which are made possible through and by the means of the welding process. In this particular field of application, vast savings are being effected by the railroads which have adopted the "TELEWELD PROCESS" for their rail end restoration.

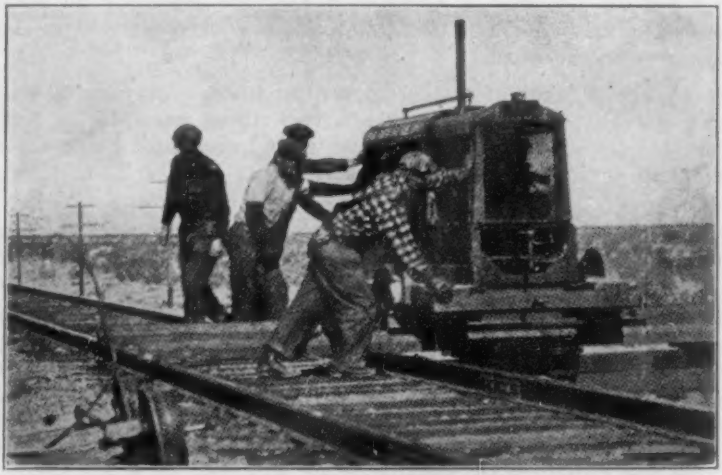


FIG. 1. SETTING THE POWER PLANT OFF THE TRACK

Our present equipment was designed after two years of research before it was placed in general service. Our first work was done in 1923, and now after more than four years' operation the process is thoroughly proved.

Each outfit consists of a generating plant, a grinder car, transformer car and a cable car.

The plant proper is a gas engine driven outfit which generates the electric power for both welding and grinding. This plant is mounted on a self-propelled car, similar in type to a track motor car, and is equipped with small double flanged transverse wheels for removing it from the track to a tie crib, or a platform built of ties or timbers entirely clear of traffic.

The cable man then strings his cable by the use of a 4-wheeled cable carrier. One-half mile of cable is strung along one side of the track for welding purpose and another cable of equal length on the other

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†Electric Railweld Service Corp., Chicago.

side of the track for grinding purposes. In this manner work is carried on one-half mile each way from the generating plant which permits one mile of welding from each set-off. Hence our slogan—"A mile at a time."

The foreman then inspects each joint and with the use of a straight edge, determines and marks the extent of welding necessary to restore the rail ends to a perfect condition. A workman proceeds to

FIG. 2. LEFT—CHIPPING OFF LAMINATED METAL BEFORE WELDING

FIG. 3. RIGHT—WELDER AT WORK ONE-HALF MILE FROM THE POWER PLANT

chip out all fatigued, flaked, laminated or chipped metal by means of a chisel and hammer.

The welding operator commences, as shown in Fig. 3, and you will note the grinder directly behind. Typical chipped and battered joints are shown in Fig. 7. In Fig. 8 is a joint built up, but which has not been ground.

The electric surface grinder follows up immediately behind the welder. This unit, shown in Fig. 4 is a highly developed piece of equipment. With it the rail ends are ground to perfect precision, using a grinding stone 2 in. x 14 in., which travels about 2200 r.p.m.

Next comes the hand grinder, shown in Fig. 5. The stone used in this case is only 3/16 in. thick and travels 4000 r.p.m. The purpose of this operation is to cross-cut the weld, which restores expansion at that section and slightly bevels each rail end. Surface fractures are

thus prevented and metal flow-over is retarded to an absolute minimum. The picture of a finished joint—Fig. 6—quite clearly shows the result of the cross-cut.

All this work is done under contract by our own men, carefully selected and thoroughly trained in our own school, maintained for that express purpose. A normal crew for each unit consists of two welding operators, two grinders, one engine man, a cable man and two

FIG. 4. GRINDING JOINT TO A TRUE SURFACE

FIG. 5. CHAMFERING JOINT AFTER SURFACE GRINDING

flagmen, all in charge of an experienced supervisor. These units are electric lighted which permits us to work day and night with such a crew as mentioned above.

On average normal work, production is one mile out-of-face welding in three days for each machine, working day and night. This means about 320 joints or 640 rail ends. Normal organization is two

machines or outfits working on a stretch together with a combined production of two miles in three days.

For rail end restoration, the "TELEWELD PROCESS" rightfully claims the following features:

The welding heat is localized and there is no softening or annealing of the rail ends. The joint bars, bolts, insulated joints and welded

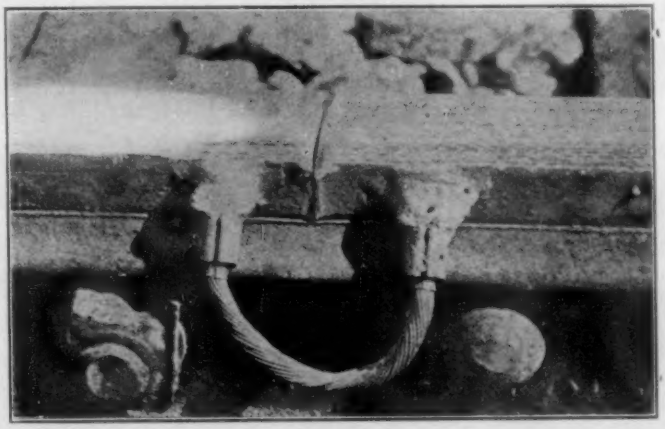

FIG. 6. REBUILT RAIL ENDS GOOD AS NEW

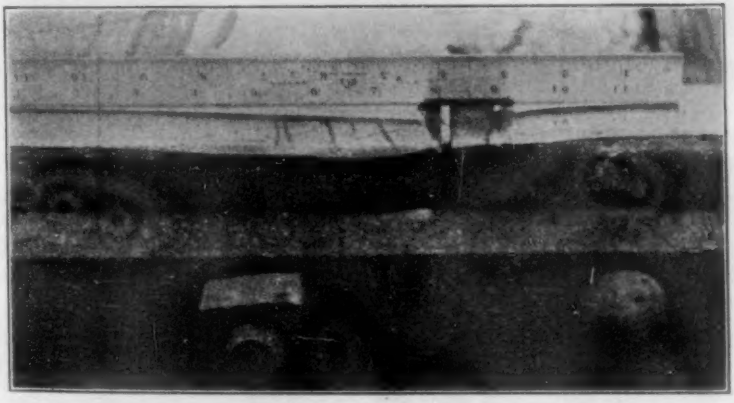

FIG. 7. TYPICAL EXAMPLE OF BATTERED AND CRIPPLED RAIL ENDS

signal bonds are not disturbed. There is no interference with electric signal systems and no traffic interruptions.

Long defects may be corrected because the heat is confined to the extreme upper surface of the rail. Defects in excess of 4 ft. in length have been welded.

There is no chipping or spalling of added metal, since fusion is ef-

fected through the over-strained fibers of the battered joint, and the new metal penetrates and fuses to the normal metal of the rail.

The *full section* of the rail *is restored* for the entire length of the joint bar by surface grinding with our accurate grinding machine.

Compression fractures are prevented by cross-grinding the ends of the joint.

The flow of metal at the ends of the rail is reduced to a minimum through the special composition of the materials used in the process.

Extremely economical, based on inches of area restored.

Based on our four-year-old work, it is estimated conservatively that welded joints will last six or seven years. This will represent ap-

FIG. 8. NEW METAL WELDED IN PLACE BY THE TELEWELD PROCESS BEFORE GRINDING

proximately the balance of the life of the rail proper at the period it is due for welding, in heavy main line traffic.

By the same process and with our well-trained experienced operators, most remarkable success has been attained in building up manganese crossings and frogs. The grinding units are used also in these operations. The two hundred crossings restored with their present record of service, support our claim.

More than 175,000 joints have been welded by us. Many of these were welded in 1923 and 1924 and are still in service—in excellent condition.

It was not mentioned above, and you will perhaps be interested to know that the surface grinding machine is the only unit which occupies the track during the entire operations for each set-off. The frame of the grinder is made of aluminum castings and because of its lightness, can be easily removed from the track to clear traffic.

When moving from one location to another, the power plant provides the power to move all units down the track at a speed of 20 to 25 miles per hour.

All Welded Gas Holder

By F. H. BEEBE†

THERE has just been completed at Albion, Mich., one of the largest all electric arc welded low pressure gas holders ever built in this country. The construction and design are both the work of the Western Gas Construction Co. of Fort Wayne, Ind. The holder, with all lifts elevated to their maximum height, stands 113 ft. 7 in. above the foundation. It has a diameter of 74 ft. and weighs 516,385 lb. plus the weight

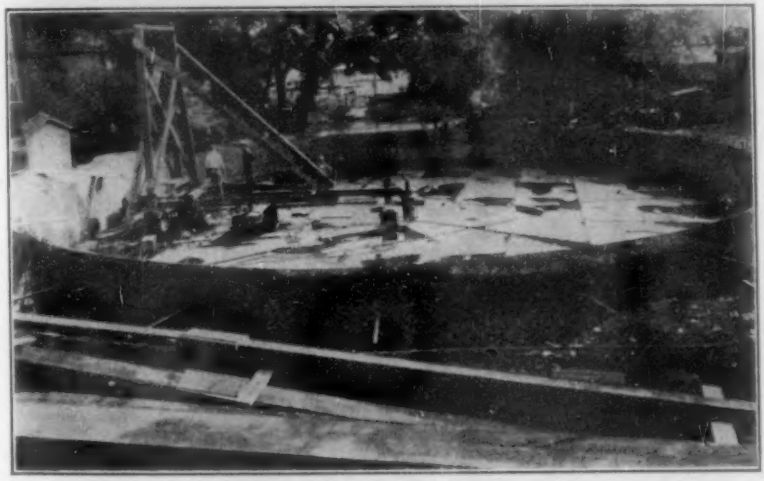

FIG. 1. GAS HOLDER WITH WATER TANK UNDER CONSTRUCTION

of the welding rod that was used. The gas holder has a capacity of 300,000 cu. ft. of gas at a water pressure, when full, of 12 in.

A 15,000 cu. ft. single lift gas holder of all arc welded steel construction was built by the Western Gas Construction Co. for the Missouri Gas and Electric Co. at Lexington, Mo., in 1924. The previous welding work done on gas holders seemed to lead logically to its exclusive use, for welded joints have proved perfectly satisfactory in structural strength and are gas and water tight. One of the great advantages of using electric welding on gas holders lies, of course, in the latter fact.

Building a gas holder by electric arc welding has inherent practical advantages that recommends it strongly. It simplifies construction and reduces fabricating cost. When a gas holder is made of riveted plates it is necessary to employ the tank shop to lay out and punch all the members. When metallic arc welding is used it is only necessary to lay out

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and punch the members in the shop for fitting up bolts. The plates are, of course, rolled to the proper radii in the shops. On this job the plates were assembled in position with bolts and tack welded with the exception of the cups and grips, which were fabricated in the shops, assembled in sections on the ground, and welded in place.

Figure No. 1 shows the gas holder with the water tank under construction. The bottom was assembled and welded on the foundation which was 3 ft. below yard level and incidentally in this case, below the

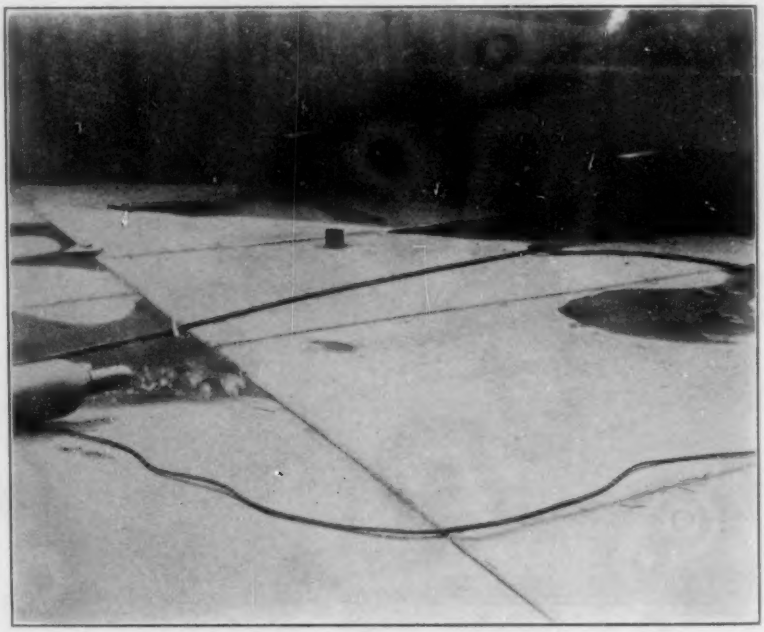

FIG. 2. BOTTOM OF TANK

water line. Excavation was made around the foundation forming a pit, in the center of which was the foundation. The bottom and first course was built on the foundation and water was allowed to stand in the pit at a height of about 12 in. above the foundation. In this manner the bottom and lower curb was tested for leaks and it is interesting to know that none were found.

The structure shown in Fig. No. 2, against the circular plates in the upper right-hand corner, is what is known in gas holder construction as a cup. The ease with which these cups were built by electric welding is quite clearly shown. I-beams were welded together and to the floor, forming the landing blocks. In Fig. No. 2 one of the temporary construction joints can be clearly seen behind the cup. The preliminary bolts and tack welding are just above the right cup support.

Fig. No. 3 shows the gas holder at the time of the completion of the water tank. When this photograph was taken the final welding was in

process. The joints were of the lap type, a variety easy to weld. In this picture a fairly comprehensible suggestion of the bracing may be glimpsed above the upper course. It was not elaborate and consisted of virtually the same elements that would be necessary on a riveted job. All through this work it was the simplicity of welding that was its greatest virtue.

Fig. No. 4 shows the gas holder after completion. In these views the guide frame may be seen. This frame was entirely arc welded, the only

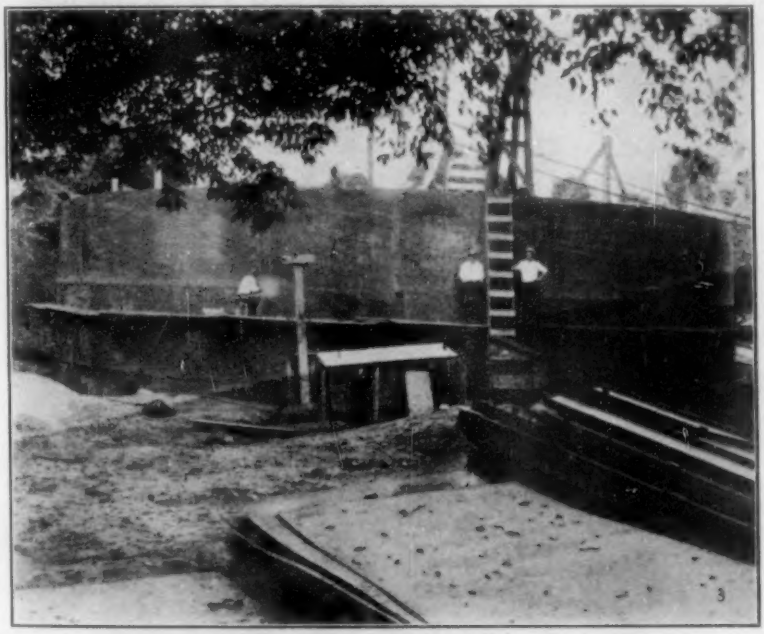

FIG. 3. GAS HOLDER WITH WATER TANK COMPLETED

bolts that were used being those employed in assembly. Around the top of the different lifts can be seen the goose necks. In the past these have been of riveted construction. On this job they were fabricated with metal arc welding.

For the information of those who may wonder about the plates that form the sides, it might be well to state that the water tank ranges from 7/16 in. to ¼ in. stock and the three lifts of No. 10 gage. Everything on this gas holder, as has been stated before, is completely welded. There are no other types of joints, the ladders and the platforms being assembled by welding.

Fig. No. 5 shows the crown of the upper section being laid. In laying this crown a wooden under structure was built on which the plates could be laid. When this was ready the plates were swung into position and tack welded. They were laid in circular rows from the outside to the

center, each succeeding course being lapped over the one before. As the plates were placed they were tack welded to hold them in position, and when all was ready the finishing welds were made.

On this gas holder four tons of electrode welding rod were used. If a holder of the same size were made of riveted construction, 7½ tons

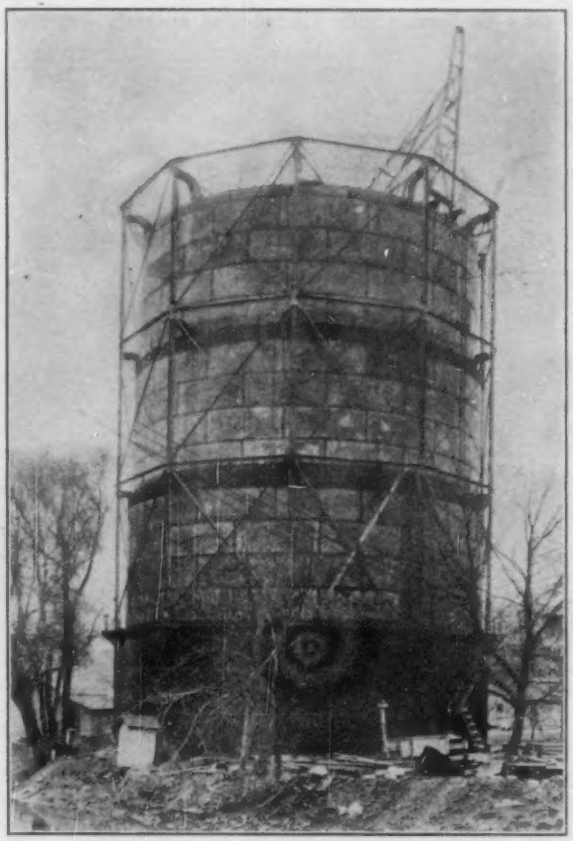

FIG. 4. GAS HOLDER AFTER COMPLETION

of rivets would be necessary. Four arc welding machines were used in placing 21,414 lineal feet of welding. The entire job was carried through almost without a hitch and with much less difficulty than would naturally be expected with a new structural process. It seems beyond a doubt that in the future gas holders will be fabricated by electric welding as a matter of course. There is so much to recommend it that it will inevitably find universal adoption. The great benefits, as has been said before, lie in the facts as that: first, by using welding the greater part of the shop fabrication is eliminated; second, that after the structure is once

tested and freed from leaks there is little or no chance for trouble to develop.

The holder at Albion, Mich., was built largely through the cooperation

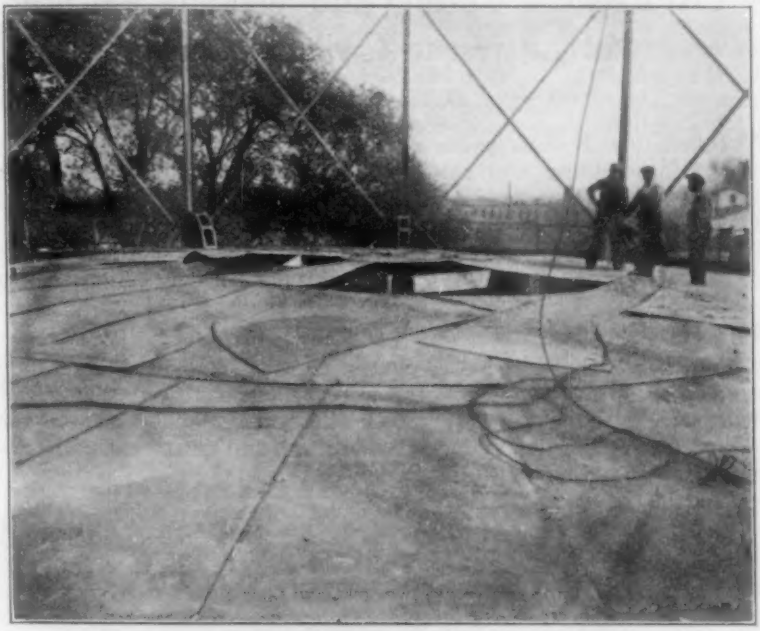

FIG. 5. WELDING THE CROWN OF THE UPPER SECTION

of D. F. Burritt, vice-president in charge of engineering of the Middle West Utilities Co., Chicago, Ill., and Roy Campbell, president of the Albion Gas Light Co., who are ever alert to the possibilities of newer and better construction of equipment.

Oxyacetylene Cutting and Welding Practices of Interest to Civil Engineers*

By C. A. DALEY†

IN this paper I shall endeavor to point out some practices in oxyacetylene welding and cutting in which the civil engineer is most likely to be interested and to encounter in the practice of his profession.

In our modern construction steel plays an important rôle. You can see everywhere about you steel replacing wood construction. Our ships, our bridges, our buildings, even our furniture are now being constructed of steel. Is it little wonder, then, that the oxyacetylene welding and cutting torches have come into common use?

The carpenter has his saws, planes, chisels, hammers, nails, etc., for working and joining wood, but the working of steel by the older conventional methods requires an altogether different set of tools, the operation of which generally involves heavy machinery and power. This limits the preparation of steel work in large degree to a shop.

The invention of the oxyacetylene cutting and welding torches has furnished the steel worker with his most useful modern tools. They are light and portable and may be used anywhere. If a heavy plate, I-beam, or other heavy section has to be cut, the torch can be easily taken to the job instead of taking the job to a stationary machine, which would involve the use of a crane or some other means of transportation.

Oxyacetylene Welding and Cutting as Applied to Railroad Maintenance

In railroad maintenance the oxyacetylene torch plays an important part to reduce maintenance expense. One tune the maintenance engineer always hears is "Keep expenses down." Here, the torch is his friend.

A 130-pound section rail in place in the track is worth approximately $40. You can readily appreciate the expense a maintenance engineer must provide for in his budget to take care of this single item. Then, too, there are the numerous crossings, frogs, and switches which must be provided for. Naturally, therefore, he is interested in getting the longest possible life out of these costly materials, consistent with safety and good riding track.

When rail ends begin to batter, maintenance expense begins to mount. The battered ends cause excessive wear in the bolt and angle bars, loose joints, shattered ties, and rough riding track. Even the ballast is dislodged by the hammering of the wheels as they pass over the battered joints. This bad condition must be looked after frequently by the section men. Bolts must be tightened, angle bars renewed if worn or

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†Maintenance of Way Engineer, Air Reduction Sales Co., New York.

broken, and the joints tamped up, or even worse conditions, such as wide gage and poor alignment, will develop.

The first all-iron rail used in this country was on the Camden-Amboy Railroad in 1848. This rail, 7 in. high, had a base 4⅝ in. wide. It was thought at the time that the rail problem had been solved as it was apparently a distinct improvement over the iron topped wooden rail, but it was soon found that the rail battered very badly at the ends, and this in turn caused considerable shock and damage to the rolling equipment. After a year or so these rails were replaced with the old iron topped wooden rails.

This was the first instance of rail batter, a problem which today confronts railroad engineers everywhere. In 1848 they took the rails out, but today, with the aid of the welding torch, battered rails are being built up in the track at small cost without interruption of traffic.

To illustrate the value of the welding torch in building up battered rail ends, suppose a battered joint has developed in a track laid with 130-pound rails and it is desired to correct the bad condition. If no welding torch were available, it would be necessary to replace two rails. These rails, as mentioned before, are worth in place approximately $40 apiece. Therefore, it would require an $80 outlay to repair the bad condition. Of course the rails removed have a small salvage value, but it is only small compared to the $80 expenditure.

With a welding torch and special welding rod suitable for this work, a battered joint can be built up for approximately $1.50, and repaired rail ends will be better than when new, that is, they will stand more traffic.

The operation of building up battered rail ends is not difficult, and it can be done in the track, as before stated, without interfering with traffic. The joint to be built up is surfaced to the proper elevation by the section men and new bolts and angle bars are applied where necessary. The welder determines the amount of metal to be added and the distance the weld must be carried back by placing a short straight edge on top of the rail. He takes his torch and melts out all the loose and fatigued metal. The torch is then directed upon the end of the rail and when the metal has been brought to a molten condition the special welding rod is added, working in both directions until sufficient metal is added to eliminate the batter and bring the rail surface up to the common level. If the rails are close together, the weld can be carried across the joint and then the weld metal can be cut at the joint with a hot chisel. The whole weld is then heated and given a final smoothing with a blacksmith's flatter.

Frog Welding

Frog welding like rail end welding may also be done in traffic. A No. 10 100-pound open hearth rigid frog costs approximately $125. This frog when worn to the point of replacement can be built up by the oxyacetylene process for what it would cost in labor alone to replace it with a new frog.

A frog that has been given ordinary maintenance attention, that is, one in which the bolts have been kept tight so that the fillers and bolt

holes are in good shape, can be rewelded several times. Thus, with a welding torch the number of frogs carried in stock for renewals can be materially reduced.

Switch Point Welding

The switch point, unlike other parts of the track structure, presents only a thin fin of metal to withstand the shocks and abrasive effects of car and engine wheels. Especially is this true of the deflecting point.

A switch point built up against a worn stock rail will outwear by far a new point in the same location for the reason that the built-up point will have the same contours and height as the worn stock rail, whereas a new switch point applied against a worn stock rail does not conform and will as a result soon be ruined.

It costs about $5 to rebuild a worn switch point, while a new 100-pound point costs approximately $25. It costs more for labor to install a new point than to build up the average worn point.

Welding Rails Together

In constructing tracks through and across streets and highways it is desirable to eliminate as many joints as possible in the traveled way because these are a source of trouble from a maintenance standpoint. Special long lengths of rails can be obtained for this purpose, but they are costly and hard to handle, and when you want one badly at one location it is generally somewhere else.

Here again welding and cutting torches are indispensable for efficient low cost track maintenance. The ordinary length rails can be welded together and the angle bars replaced making the rail continuous.

To make rail welds the rails are veed with the cutting torch across the bottom of the base, up the web, and on both sides of the ball in toward the center. Angle bars are then applied to insure proper alignment of the rails and are kept on until the weld is completed across the base. The angle bars are then removed and the weld completed, working from the bottom of the web up. When the weld has cooled off sufficiently the angle bars should be reapplied and fully bolted. As many rails as desired can be welded into one continuous member in this manner.

Track Bonding

The most essential thing in automatic signaling and train control is a good track circuit. If bonding is poor, trains will be delayed, and battery consumption will be excessive.

The wire bond was used exclusively in bonding rails for automatic train signaling until a few years ago. Now, the fusion bond is rapidly replacing the old wire bond. The advantages of a fusion bond over a wire bond are as follows:

The welded bond is shorter than the wire bond and, therefore, affords greater protection. With the wire bond, a rail could be broken at the end of the angle bars or the whole head of the rail within the limits of the angle bar could be broken out and yet the track circuit would be intact and a clear signal indication given. With the welded bond applied

to the head of the rail and at the very ends of the rail, complete protection is afforded.

The resistance of a welded bond is about 1/90 of that of the common wire bond. Therefore, battery consumption is materially reduced, resulting in savings ranging from $35 to $90 per mile of track per year. The cost of the two types of bonds, wire and welded, is about the same when in place.

The operation of applying welded bonds is as follows: A man goes ahead of the welder and places the bonds on the outside of the head of the rail over the angle bar. The bonds are held in place by a simple but cleverly constructed holder made from a piece of welding rod.

The welder first heats and tins the rail at the point where the bond is to be applied. He then proceeds to weld the copper bond to the steel rail using a flux rod designed especially for this purpose. A good welder will apply an average of thirty-five bonds per hour.

Structural Steel Cutting

The cutting torch is especially valuable in the structural steel fabricating shop. It is to the steel worker what the hand saw is to the carpenter. No steel beam, channel, angle or plate is too big or too small for this tool, and torch cutting is not limited to straight or square cuts. Circular, beveled and angular cuts are made with facility.

Automatic cutting machines have been developed for cutting irregular shapes from plates and for cutting angles, I-beams, and other rolled forms. I refer to the Oxygraph and the Radiagraph. Precise cutting can be done with these machines comparable in accuracy to roughing cuts made by machine tools. Automatic welding machines also have been developed to produce steel sections impracticable to roll.

Some time ago one of our servicemen was called upon to do some cutting in connection with the reconstruction of a large steel frame building to which several stories had been added. The new steel work was tied in with the old steel structure and it was necessary to change the supporting columns of the old structure and transfer the load to the new columns.

The foreman in charge of the steel work pointed out the cross beams and braces to be cut. He knew that these members were heavily stressed and thought that by cutting them first it would make easier the removal of the old columns. But our serviceman, after looking the situation over, suggested cutting through the supporting columns first, gradually shifting the load to the new supports. This could be done readily as the kerf cut with the torch is less than ⅛ of an inch, and as many cuts could be made side by side as necessary to release the load. This method was carried out, and after the old columns were relieved of the load all the braces and cross beams were cut without difficulty.

This is one instance where the cutting torch served also the purpose of a number of jacks.

Cutting Under Air Pressure

One of the greatest engineering achievements of recent years is the newly opened Holland Tunnel. Its successful completion is a monument

to the engineering profession. The maintenance and operation of the tunnel after its completion involves more engineering than the average person realizes.

Even in this marvelous piece of work the welding and cutting torches played their parts and played them well. The shells of the cutting shields used in the construction of this tunnel were 30 feet in diameter and were made of riveted plate sections. The inside of each riveted joint was made air tight by welding. The shields were reinforced with heavy cross beams, braces, and cast steel members.

In order to start these shields it was necessary to make openings in the sides of the steel caissons which had been sunk off the ends of the piers on both the New York and New Jersey sides. The task of making these large openings 30 feet in diameter in the caissons 30 feet under the bottom of the river was accomplished with the aid of the oxy-acetylene cutting torch. Then the 30-foot circular sections taken from the sides of the caissons had to be cut up so that they could be removed from the air locks.

When the headings met in the center of the river, the shells of the shields were left in place, but all the crosses, beams, braces, and so forth, had to be removed. These also were removed with the aid of the cutting torch. Most of this cutting was done under air pressure of from 30 to 40 pounds per square inch. In all, there were twelve such cutting shields which were handled in this manner. These cutting operations consumed a large volume of oxygen and acetylene as the sections were very heavy.

Contractor Equipment Easily Repaired

The contractor of today who handles large size jobs must have machinery such as excavators, steam shovels, drills, air compressors, trucks, and so forth. Any one of these machines may break down at a critical time when it is most needed and thus disrupt the whole organization.

With the welding torch broken gears, struts, rods, braces, and so forth, can be repaired on the job quickly and effectively. We have often been called upon for a rush job to build up broken gear teeth. Broken gear teeth can be replaced without removing the wheel from the shaft, and the repaired teeth will be as strong as the others. In building up gear teeth the metal can be worked with the torch so that machining is not necessary. Dipper teeth also can be built up by welding at comparatively small cost. A special welding rod is provided for such parts subjected to heavy wear.

Bridge Repair

The cutting torch has become one of the most useful tools to the bridge man, both in the repair of bridges and for the demolition of old bridges. If a bridge is damaged by accident, or if a member becomes deteriorated by rust, it is an easy matter with the aid of a cutting torch to replace it with a member prepared on the job. Without the torch it would be necessary to have the member got out in a shop where shears and drills are available.

When the train shed at Pittsburgh was partly destroyed by fire a

couple of years ago, it was a serious question how to remove the warped and twisted trusses without interference of traffic. The cutting torch and a crane solved the problem. The trusses were cut into sections that could be easily handled and loaded into cars. The work was accomplished in record time without interruption of train movements.

Pipe Welding

Two of the most important items to consider in pipe line work and plumbing are flow resistance and tight joints. If the joints are not tight, there is loss, and if the inside of the pipe is rough there is loss. In the former case there is loss of water, gas, oil, steam, or whatever the pipe is conducting. In the latter, the loss is due to friction. In either case the loss is a financial loss.

In hot water heating the efficiency of the system depends entirely on the proper circulation of the water. If the pipe joints were perfectly smooth, the friction in the pipe would be reduced to a minimum and a better and more efficient system could be had. Plumbers and steamfitters realize this, and the up to date men are using the torch more and more in their trade.

In the oil and gas fields pipe welding has become a standard practice. A welded joint not only affords a joint with less friction than the standard screw joint but it makes a stronger joint. The full thickness of the wall of the pipe is used and it can be slightly reinforced, whereas with the thread joint the effective thickness of the wall of the pipe is reduced as much as 45 per cent in a 2-inch pipe and 26 per cent in a 16-inch pipe.

Another thing which causes appreciation of the value of the welding and cutting torches in the construction of pipe lines is the ease with which fittings, such as tees, ells, wyes, and bends can be made in the field from the pipe on hand. No special pipe or fittings need be carried along. If it be desired to make a tee connection, all that is necessary to do is to cut off the end of the branch pipe and cut a companion hole in the main pipe. These pipes are cut with a torch along the lines of intersection. The exact cutting line can be marked on the pipe by the use of templets which have been previously developed for the size of pipe in use. When the pipes are cut they are tacked in place and then welded. If a valve or standard thread connection is desired, all that is necessary to provide for this is to weld on a nipple with standard thread.

To those not familiar with the welding torch it may be of interest to know that the oxyacetylene flame temperature is approximately 6300 deg. Fahr., which is sufficient to melt all commercial metals. This high temperature is obtained by burning acetylene gas with pure oxygen. No other fuel gas will produce this extremely high temperature.

By regulating the mixture of oxygen and acetylene in the torch it is possible to produce three characteristic flames—carburizing, neutral, and oxidizing flames. The neutral flame is generally used, although the carburizing flame is sometimes used in welding non-ferrous metals and alloy steels.

The cutting of iron or cast iron with the oxyacetylene torch is made

possible by virtue of the fact that iron and steel will burn in an atmosphere of oxygen. The cutting torch is designed so as to make this condition ideal. The tip of the cutting torch is so made that it will produce what is known as a preheating flame or flames. The preheating flame brings the steel, iron or cast iron to its kindling temperature. Then with the manipulation of the valve a jet of pure oxygen is released and directed on the hot metal. Burning or cutting takes place, producing a cut with narrow kerf comparable to that made by a saw.

The uses of welding and cutting torches mentioned in the foregoing by no means cover all the practices with which the civil engineer will come in contact. The field is very broad and its limits not defined. New uses develop daily, and the indications for the future are that welding and cutting will be processes indispensable to the civil engineering profession.

An Arc Welded Railroad Bridge

By A. G. BISSELL†

THE use of a process increases as the confidence of the user grows. In the past few years the confidence in metal arc welding has developed to a point which has resulted in the process being accepted by many industries as a standard fabricating method. The

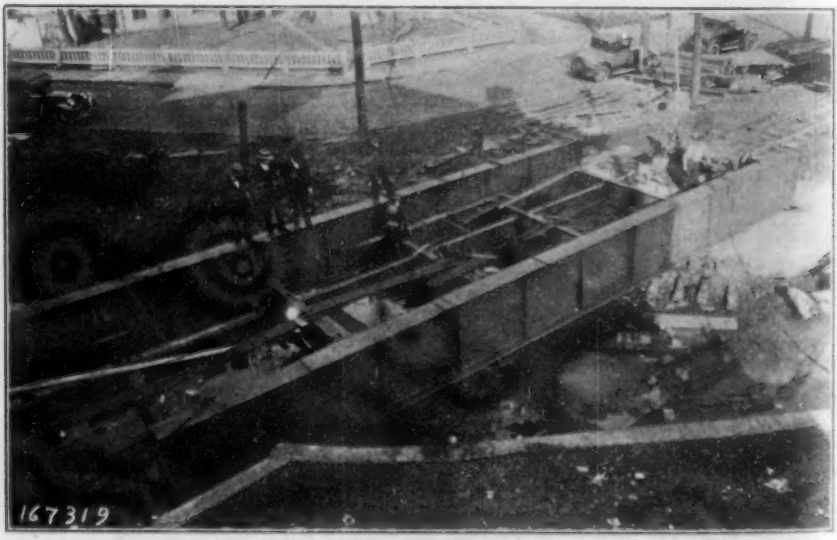

FIG. 1. GENERAL VIEW OF BRIDGE

railroads for years have used arc welding in their locomotive repair and fire box construction work. Much work has been done with arc welding in steel ship construction. The members of steel buildings have been joined by the same process. Large electrical motor and

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generator frames and bases are being fabricated by arc welding. All of which indicate the widespread confidence which the arc welding process has created in the various industrial fields today.

An excellent example of the confidence of our company in arc welded construction is exhibited by the construction of a single span, girder type, standard gage railroad bridge on the Turtle Creek and Allegheny River R.R. at Hunter's Crossing, Turtle Creek, Pa. This bridge carries the rail traffic between the Linhart Works and the East Pittsburgh Works of the Westinghouse Company and is designed

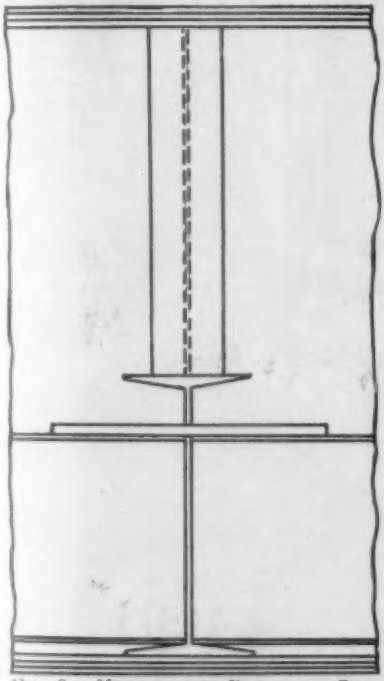

FIG. 2. METHOD FOR PROVIDING CONTINUOUS STRINGERS

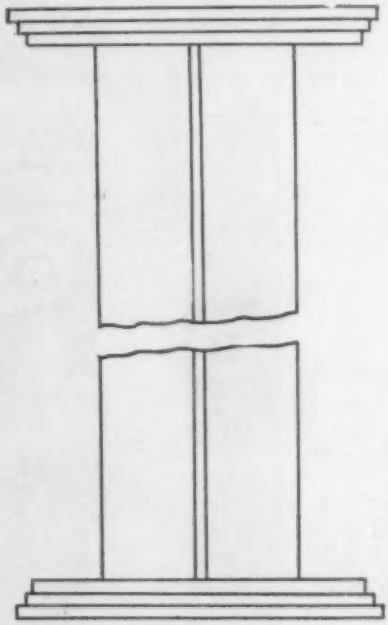

FIG. 3. WIDTH OF COVER PLATES PERMITS WELDING ALONG EDGES

to carry a 185,000-lb. locomotive on three sets of drivers. This bridge was completed November 5, 1927.

This bridge consists of two fabricated girders 4 ft. 11¼ in. deep and 52 ft. 5 in. and 53 ft. 9 in. long, each weighing about 11,600 lb. The bridge crossing Thompsons Run at an angle of about 60 deg. and the foundation walls not being parallel required an offset of the girders at one end of 10 ft. 11 in. and 9 ft. 7 in. at the other, as shown in the General Plan, Fig. 1. This gives the bridge an overall length of 63 ft. 4 in. Its width is 15 ft. between girder webs. To connect the girders five 24-in. 99-lb. I floor beams were used and between these floor beams 18-in. 54.7-lb. Is were used as longitudinal stringers. To make these stringers continuous a slot was cut in the webs of the floor beams to permit a ¾-in. x 5-in. x 24-in. plate to pass through, as

shown in Fig. 2. These plates were welded to the upper flanges of the 18-in. stringers, giving a continuous beam to support the track ties. Diagonal bracing of 3-in. x 3-in. x ¼-in. angles were attached between the bottom flanges of the girders and floor beams as shown in the General Plan.

The girders were constructed in the field at the East Pittsburgh Works using a locomotive crane for making the necessary lifts. When

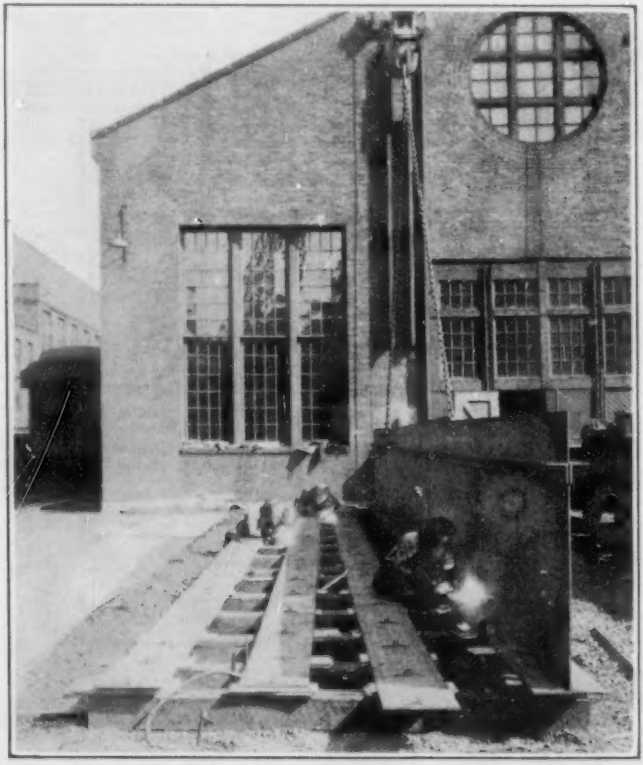

FIG. 4. FABRICATING STEEL GIRDERS FROM FLAT PLATES. TEMPORARY CLIP ANGLES ON COVER PLATES USED TO LOCATE WEB UNTIL TACK WELDING IS COMPLETE. STIFFENER ANGLES NEAR TOP OF WEB ARE BOLTED TEMPORARILY TO THE WEB TO ASSIST IN HANDLING. ARRANGEMENT OF WORK PLANNED FOR DOWNWARD WELDING

the girders were completed the entire bridge was assembled on blocks without welding, to check the fit of the members. The parts were then loaded on flat cars and taken to the site. The old bridge was torn out, the new bridge girders swung into place and the floor beams and stringers placed and welded in. About three days were required before the tracks were replaced and traffic resumed.

The girders were built up entirely of flat plates which construction is quite a feature in arc welded construction. The flanges are made

of three plates. The first to which the $\frac{3}{8}$-in. x 54-in. web is attached by two $\frac{3}{8}$-in. fillet welds is $\frac{5}{8}$ in. x 1 ft.-$2\frac{1}{2}$ in., extending the length of the web. To this plate is attached a cover plate $\frac{1}{2}$ in. x 1 ft.-$3\frac{1}{4}$ in. x 38 ft. Then a second cover plate $\frac{1}{2}$ in. x 1 ft. 4 in. x 22 ft. is attached. It will be noticed in Fig. 3 that the flange and cover plate widths are such that a fillet weld put in at the plate edges secures them together. In attaching the web plate to the flanges, two 6-in. x 6-in. x $\frac{1}{2}$-in. angles were bolted to the web plate, as shown in Fig. 4, to give the web rigidity in handling. The small angles shown tacked along the center line of the flange were used to aid in locating the web until it was tacked when the angles were removed. When the web was secured to the first flange the web stiffeners, $\frac{3}{8}$ in. x 4 x 4 ft. 6 in., were located and welded in. This permitted the welding between the end of the stiffener and the flange to be done in the downward

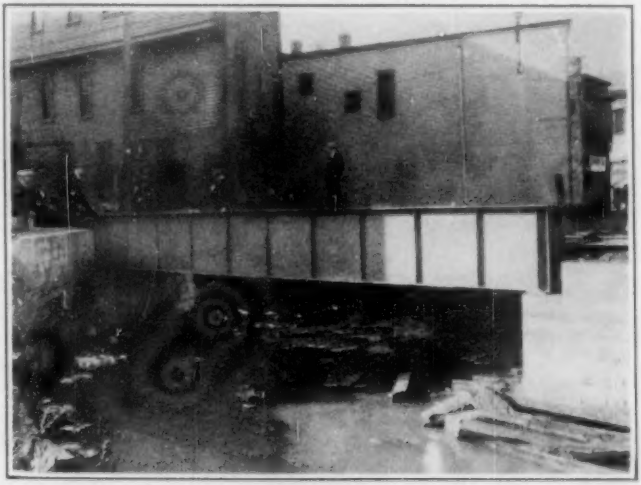

FIG. 5. SHOWING SIDE VIEW OF ARC-WELDED PLATE GIRDER RAILWAY BRIDGE WITH 55-FT. SPAN

position. When the first flange and the web stiffener were welded, the whole was picked up by a locomotive crane, turned over, and the web edge located between the small angles on the second flange and the remainder of the welding completed. Three-eighth-inch fillet welds were used at the flange plate edges and between the flange and web 5/16-in. fillet welds were used between the web stiffeners and the flange and web plates. Three-eighth-inch x $14\frac{1}{2}$-in. plates were welded to the ends of each girder to give a finished appearance, which is shown in Fig. 5. The $\frac{3}{8}$ x 4-in. stiffeners were omitted where the floor beams were attached to the web and in their places $\frac{3}{8}$-in. plates 14 in. wide at the end joining the floor beam and tapering to 4 in. at the top were installed. These combination stiffeners and braces were finished off with a $\frac{3}{8}$-in. x 6-in. plate as a flange.

In the construction of the girders three welders were employed and in the assembly at the site 6 welders were used. The welding cur-

rent was supplied by single operator motor generator sets. One thousand and sixty-seven linear feet of ⅜-in. fillet welds and 501 lin. ft. of ⅜-in. fillet welds and 501 lin. ft. of 5/16-in. fillet welds were put in on this job requiring about 500 lb. of electrode material and 320 man-hours of welder time. A total of 39,200 lb. of steel was used in the structure.

After the bridge was completed it was tested by running a 185,000-lb. locomotive over it at various speeds. No evidence of weakness was discovered. In fact, it was evident that the bridge was more rigid than other types of construction of the same weight.

In order to gain confidence in the arc welding process it is necessary that it be used under competent supervision with trained operators. Any industry using arc welding to a large extent should employ a welding engineer. The welding engineer should preferably be a

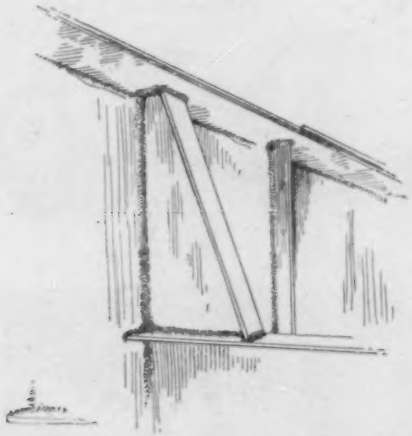

FIG. 3. COMBINATION STIFFENER AND KNEEBRACE AT FLOOR-BEAM CONNECTION TO GIRDER

man with an engineering education, who has had much practical experience in all branches of welding. He should know his operators and thus select the men for the job according to their ability. The welding engineer should also have full authority in the selection of the operators and welding equipment used.

The design of parts to be welded is an important feature and when properly executed will result in a saving of a material in most all cases. The saving in weight of steel is due to the elimination of gussets and connection angles. This also is due to a reduction in cross sections of members because of more complete fixation of the joints and no loss of material for rivet holes.

Confidence, supplemented by competent supervision, experienced operators and modern welding apparatus has thus brought the arc welding process to a stage where it is used successfully in bridge construction. This is the first bridge. A second at Chicopee Falls, Mass., is under construction and, no doubt, more will follow.

Easy Method for Testing Welds for Ductility*

W. B. MILLER†

FIRMS which use welding are always receptive to suggestions of simple methods for the periodic testing of the work of their employees and the character of the raw materials used in fabrication. The bend test outlined here is easy to carry out in the shop. It has been devised to demonstrate the actual ductility of weld metal in a joint—not the strength of the weld nor the angle to which a sample can be bent. The only equipment necessary is a vise, a hammer, a marking punch, and a flexible steel rule scaled to hundredths of an inch.

The results of the test are given in the actual percentage of elongation of the weld metal, usually on a 1-in. gauge length. Controls of the test can be kept by first bending coupons of the plate before it is welded and by comparing the results of these tests with the outcome of the investigations made on welded specimens. It tests the weld metal itself and not a portion of the plate, as is often the case when a tensile testing machine is used; the break in this bend test should come in the weld metal to make it a satisfactory test.

It is very nice to have tensile testing machine results, but in most work it is difficult to get them, and even when obtainable they take time. It is also true that the angle bend test formerly employed, if incorrectly made, which is sometimes the case, does not tell anything as to the amount of ductility of the weld, the bend occurring for the most part in the plate, especially if the latter is soft and ductile. A poorly welded coupon may show a considerable bend angle, though the bending may be all in the plate. The elongation bend test here described, however, shows clearly the ductility of the weld metal in any case, giving a specific figure for its percentage of elongation.

The test proper is made by preparing two plates, usually ⅜ in. thick, bevelling each on one side to make a vee, and welding them together. If possible the operator should not be aware that the weld is to be tested. The plate is next cut into coupons about 1 in. or 1½ in. wide by 5 or 6 in. long. Coupons may be made as short as 3 in., but a little more length makes them easier to bend.

These test coupons are first prepared by grinding or smoothing down the weld, especially if it has been reinforced, then laying off the weld and adjoining metal very carefully as is shown in Fig. 1, using centre punch marks. For ordinary procedure it is sufficient to make a mark ½ in. on each side of the centre of the weld, as is shown on the coupon in Fig. 1. This coupon is about 5 in. long.

The sample is next placed in an ordinary machinist's vise, the jaws of

*Supplementing paper presented by author at Fall Meeting, A. W. S.

†Union Carbide & Carbon Res. Labs., Long Island City.

which should come about 1 in. from the punch mark, and is struck with a hammer and bent over at an angle of about 10 deg. (Fig. 3). The coupon is then reversed and the same procedure takes place on the op-

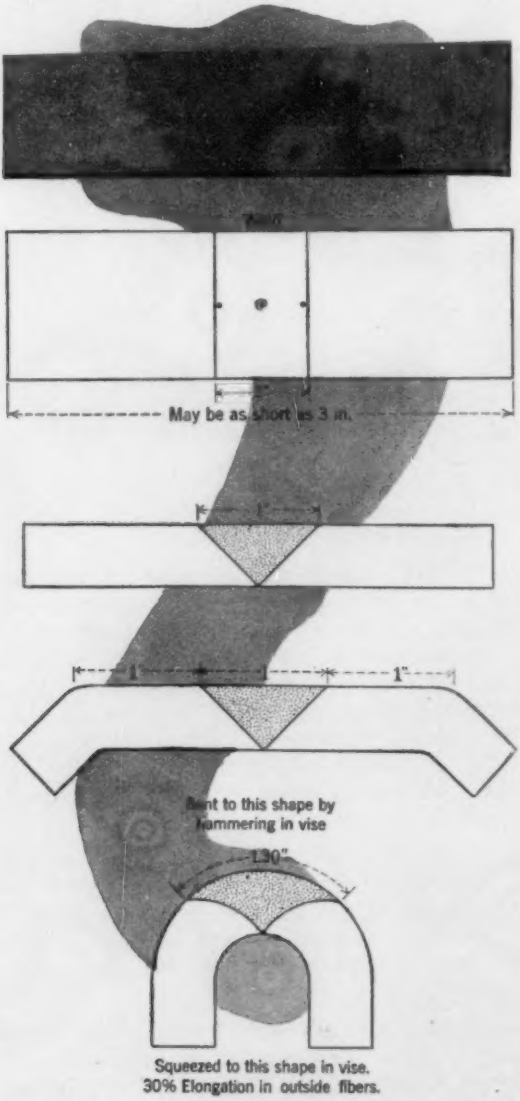

FIG. 1 (ABOVE)—HOW TO LAY OUT THE COUPONS
FIG. 2 (BOTTOM SKETCH)—COUPON BENT IN TEST

posite end (Fig. 4). It is best not to get the jaws of the vise too far from the weld metal in this hammering test because the metal outside the weld will bend and the weld metal itself remain unaffected, thus making the test worthless. It is always necessary for the greatest part

of the bending to come in the weld metal itself. The coupon as it stands ready for bending is shown in Fig. 4. It is then bent in the vise as shown in Fig. 5. This allows the bend to occur freely, which is essential for accurate and consistent results. In case the vise does not extend enough to take the coupon endwise in its jaws, the coupon can be placed between the two jaw shanks to start. If the coupon does not start to

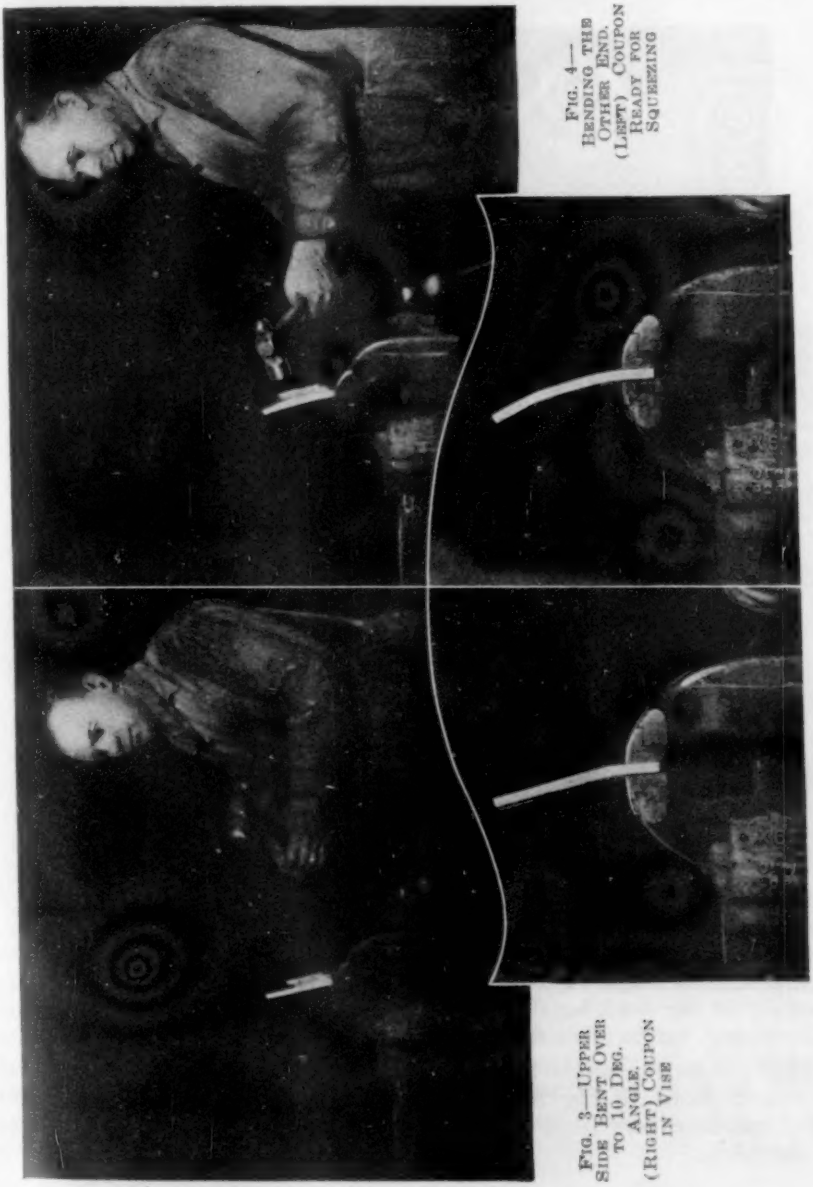

FIG. 4—BENDING THE OTHER END. (LEFT) COUPON READY FOR SQUEEZING

FIG. 3—UPPER SIDE BENT OVER TO 10 DEG. ANGLE. (RIGHT) COUPON IN VISE

bend immediately, a good plan is to exert pressure by means of a length of pipe slipped over the vise handle to give extra length and leverage.

As soon as the first crack in the weld metal is observed, the bending is stopped and the distance between the marks measured with a flexible steel scale reading to hundredths of an inch (Fig. 7). When the original distance between the marks is 1 in., the per cent of elongation is identical with the number of hundredths of an inch in excess of 1 in. in the final

FIG. 5—BENDING IN THE VISE

FIG. 6—THE BEND PROGRESSING

FIG. 7—TAKING THE MEASUREMENT

measurement. Thus in one specimen the first measurement between the points was 1 in., and the final measurement was 1.17 inches; therefore the elongation was 0.17 in. or 17 per cent. Results of some of the tests are shown in Fig. 9. This figure also shows that the usual way of measuring the angle to which a sample is bent is not a measure of the ductility of the weld, because the same per cent of elongation is obtained with 90-deg. bends (Nos. 3 and 4) as with 180-deg. bends (Nos. 8 and 9).

There is in the angle bend test this possibility of the results being misinterpreted. In Fig. 8 appears what is apparently a good bend, but there has been very little bending of the weld metal, most of it coming in the plate.

The careful measuring of the weld metal elongation by the new method will show exactly the amount of ductility in the joint. Cracks should appear first in the weld metal of a specimen in which the base metal and the weld metal have been properly fused, and the coupon correctly prepared for the bending test.

For purposes of comparison, and to judge the ability of welders, the

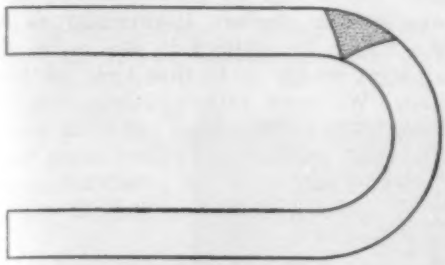

FIG. 8—INCORRECT BENDING

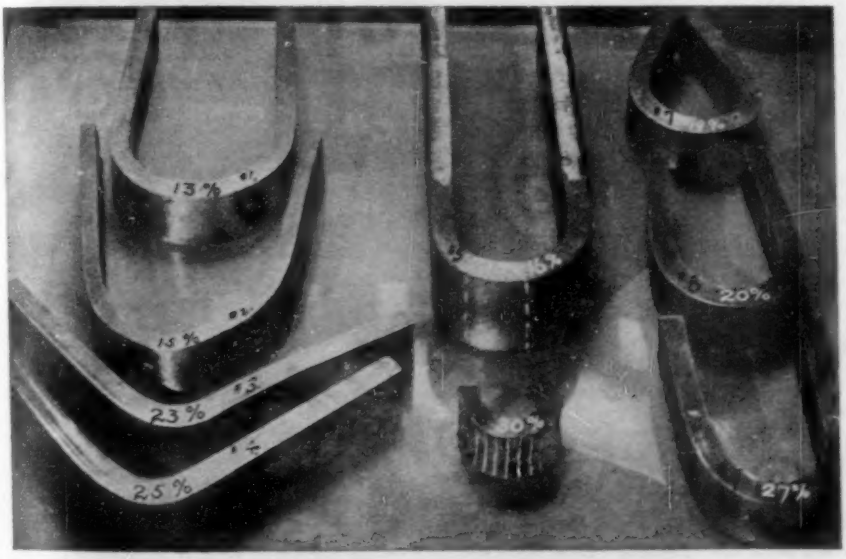

FIG. 9—COUPONS BENT FOR EXAMINATION

following results have been taken at random from some test coupons. This series of welds, made with a mild steel rod in boiler plate ⅜ in. thick, ran from 26 to 30 per cent elongation, with an average elongation of about 28. Welds made with rod for high strength welds (No. 1 High Test Rod), while stronger, were a little less ductile, showing an elongation of from 15 to 20 per cent, with a general average of about 15. These welds were the ordinary run of good welders' work, and can be considered of high standard as to ductility. In most cases the coupons can be bent much in excess of the per cent noted.

Welded Pressure Vessels*

By A. O. MILLER†

IN the year 1922 one of our very good customers approached us in regard to oxy-acetylene welding a rotary lime kiln 8 ft. dia. x 125 ft. long of $\frac{5}{8}$ in. plate, a piece of equipment which up to that time we had always made of riveted construction. We were rather skeptical as to whether we could accomplish the task, since we had done but little welding up to that time, but decided after some preliminary experiments that the plan was entirely feasible and went ahead with the construction of this kiln and also three rotary coolers 5 ft. dia. x 50 ft. long of $\frac{3}{8}$ in. plate.

FIG. 1.—THIS KILN HAS NOW BEEN IN SATISFACTORY OPERATION FOR OVER 4 YEARS

After four years of continuous operation we are pleased to state that all of these have given entire satisfaction. The welded lime kiln costs less to operate than its two mates alongside, which are of riveted construction. Very extensive strain gage measurements have demonstrated that because of the welded construction the welded kiln shell could have been made of $\frac{1}{2}$ in. steel plate and still have been stronger than the riveted ones of the same size built for the same service. This, coupled with the saving made by omitting butt straps (which amounted to about 14 per cent of the weight of the structure), would have represented a big item in itself. Over a year's period of operation, however, there is still a further saving of importance in power consumed and upkeep on bearings.

*Discussion to be presented at Annual Meeting, A. W. S., April 26, 1928.

†Vice-president, Reeves Brothers Company, Alliance, Ohio.

At the time of this undertaking we built an experimental section of kiln 24 ft. long in order to try out methods of welding and procedure and later made two heads and welded these to the experimental section, forming a cylindrical tank with dished ends. This assembly was subjected to a hydraulic test, and the pressure increased until one of the first welds made gave way for a distance of 2 in., but not before the tank had stretched in length about 2¼ in. and about 2⅛ in. in circumference. This proved to us the correctness of our procedure.

We then attempted several 7 ft. dia. x 35 ft. long storage tanks. These were for 125 lb. working pressure and ¾ in. plate of fire box quality was

FIG. 2.—WELDING A LONGITUDINAL SEAM

specified for the shell. Heads were designed in accordance with A.S.M.E. Boiler Code design formula, 1¼ in. thick, one head being equipped with a standard boiler manhead frame, the design fiber stress being 7000 lb. These tanks were tested to 125 lb. pressure, then raised to 250 lb., at which pressure all seams were hammered every 2 in. with an 8-lb. maul. The pressure was then finally raised to 375 lb. and held for three minutes. All seams throughout were double vee oxy-acetylene welded, nickel steel rod being used. Welders were required to show on test welds at least 45,000 lb. tensile strength.

We next built three additional tanks of the same thickness and for the same pressure, then four more of 11/16 in. plate in shell for same pressure, the design fiber stress being 7650 lb. We then built three of ⅝ in.

plate, the design fiber stress being 8400 lb. These held up very satisfactorily on the tests.

We next tried a tank 5 ft. dia. x 43 ft. long of 1⅛ in. plate in shell, designed on 8000 lb. fiber stress in material at working pressure of 300 lb., using a standard A.S.M.E. boiler manhead in one of the heads. On completion of the tank, it was first given the regular hydrostatic test applied on all welded vessels constructed previously. This consisted in applying a pressure of 600 lb. (twice the design working pressure) and hammering all welded seams with a 10-lb. sledge. The pressure was then increased to 900 lb. (three times the design working pressure). The fiber stress at this pressure was 24,000 lb. As it was felt that 9000 lb. fiber stress could safely be used it was decided to increase the final test to 1000 lb. pressure or the equivalent of three times the working pressure

FIG. 3.—WELDING NOZZLE INTO TANK

based on the higher design stress. This pressure was applied and strain gage measurements indicated particularly high stress around the head knuckles and manhole, especially the manhole. On the second application of the 1000 lb. test pressure considerable distortion took place around the manhole and it was therefore decided to continue the test until no further permanent set occurred at test pressure or if necessary to destruction. On the third test the head failed through the manhole at 930 lb. pressure.

An examination of the ruptured head proved conclusively that the welds were in no way responsible for the failure as they were all intact, except as severed cross-sectionally together with the saddle plate and

head. On the other hand the failure proved much in favor of the welded joint, the head girth weld and the longitudinal weld in the course adjacent to the manhead being in no way affected.

This test has been described fully in papers before a joint meeting of The American Society of Mechanical Engineers and The American Welding Society, and also in issues of "Mechanical Engineering."

The fractured head of this tank was cut off and replaced with a new head, and new type of manhole made from a solid 5-in. slab turned down on the edges so that same could be welded into head. Success of this job demonstrated to us, at least, that the old A.S.M.E. riveted type design

FIG. 4.—ONE OF THE LARGEST WELDED PRESSURE VESSELS EVER BUILT

of manhole was not sufficient to withstand the higher tests that we were putting on welded vessels, namely, three times the working pressure.

We next built a number of smaller units for pressures up to 150 lb., then three oxygen receivers 6 ft. x 24 ft. of 1 in. plate for 250 lb. working pressure designed for 9000 lb. fiber stress. At about the same time we built nineteen 7 ft. x 35 ft. tanks of 15/16 in. plate in the shell for 200 lb. working pressure with the new design manhole, all of which were given the hammer test at double the working pressure and final hydrostatic test at three times the working pressure. A final air test at $1\frac{1}{2}$ times the working pressure was also given these tanks, all seams and fittings being tested with soapy water at that pressure. We are equipped to test with air up to 1800 lb. pressure, if necessary.

We next built a small experimental creosoting plant for the Western Union Telegraph Company, consisting of one retort, for 250 lb. working pressure, one reuping tank, for 125 lb. working pressure, two air receivers for 325 lb. working pressure, and one scale tank for 250 lb. working pressure, all of which have now been in operation for one year, and are giving exceptionally satisfactory service.

We then built six oxygen receivers of $1\frac{1}{4}$ in. plate for 300 lb. working

pressure, design fiber stress of 9000 lb., which were given the same tests as the previous vessels.

Our success in building the foregoing vessels led us to try for similar work in other lines of service and we secured from The Ohio Wood Preserving Company, of Orrville, Ohio, an order for two creosoting retorts 90 in. dia. x 90 ft. long, three pressure measuring tanks 90 in. x 19 ft. high, one reuping tank 90 in. x 55 ft. long, and two vapor drums 5 ft. x 16 ft. long. The retort was designed for 200 lb. working pressure, pressure measuring tanks for 200 lb. working pressure, reuping tanks

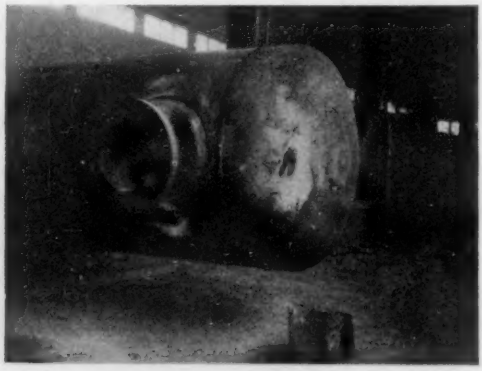

FIG. 5.—DISHED HEAD WELDED IN PLACE. FORGED NOZZLE SET UP FOR WELDING

for 125 lb. and vapor drums 125 lb. The retort itself presented the greatest difficulties as the door on the end of the retort was a real problem. We had to find a grade of steel casting which was of high tensile strength and which could be welded satisfactorily without affecting the tensile strength. This we accomplished very satisfactorily. The cylinder was made of 1 in. steel plate, rear head 1¼ in. thick, front or door head of 1⅜ in. plate, machined to template and the cast steel door ring shrunk on, then drilled, riveted and rivets electric welded.

All vessels were double vee oxy-acetylene welded with high test rod throughout and were all given a hammer test at double their working pressure, and then finally raised to three times the working pressure and held for three minutes, all having stood these tests very satisfactorily.

The welded type of vessel offers possibilities to any manufacturer using pressure vessels—first, in that it is absolutely tight against leakage of any sort, even of the most volatile liquids. Second, if it is desired to use a different process, welded vessels can be cleaned very readily and easily. No bad effects are occasioned by mixing or discoloring the second material used, through material left in riveted joints or seams from the first operation. Third, while original cost of installation may be somewhat higher this is more than offset by flexibility of operation and exceptionally low maintenance costs. Fourth, safety is increased by having a vessel with a known safety factor of three or more. With present

designs of riveted vessels, no one is sure of more than a factor of 1½, as this is all that is provided for in riveted vessel construction tests.

In choosing our men for welders on this class of work, we endeavor to pick from our plant employees men whom we know to be reliable, steady, sober and conscientious, and whom we feel can be depended upon to follow strictly any rules or regulations laid down to them to follow. Then we put them first to work in the fitting-up gangs, tending generator, gas cutting, doing small odd jobs of welding not requiring any specific strength or test, with the idea in mind that they will absorb a very considerable amount of knowledge of the actual welding by being in close

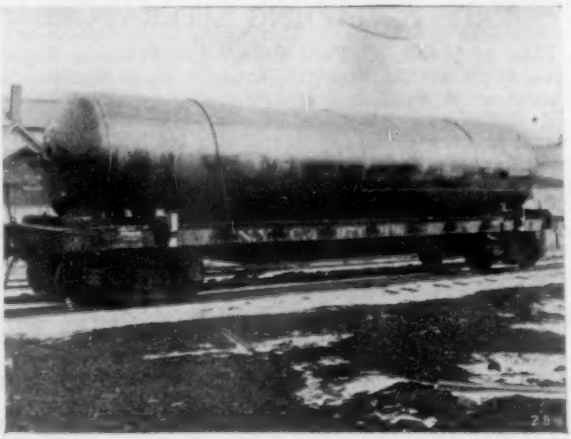

FIG. 6.—READY FOR USE

contact with the men actually welding on the vessels. They are finally permitted to weld test pieces, which are cut and broken at our plant and the results shown them as to penetration, fusion, laps, etc. Possibly after tests such as the above, we permit them to make a tensile test plate, which is sent to some authorized testing laboratory for testing. No welder has been permitted to weld on important work until all six pieces cut from a test piece have passed 45,000 lb. tensile test. On three specimens of each test the reinforcement is ground off flush. The bulk of fractures in each test piece have taken place in the base plate metal.

The tensile requirement on test pieces has now been raised to 50,000 lb. and our welders have satisfactorily passed tests at this figure on various thicknesses of plates. They are frequently checked up by having test pieces made and pulled at a recognized testing laboratory.

To show that our procedure methods and design figures are on the safe side, we just built two 7 ft. x 35 ft. tanks of ½ in. plate, designed for working pressure of 100 lb. per sq. in. These were subjected to 375 lb. final hydrostatic pressure, or 31,500 stress in the plates. This test was passed very satisfactorily with no apparent distortion, and the tested vessels then showed a known factor of 3½ based on 9000 lb. design stress.

We have just completed some very interesting pieces of chemical

equipment, for one of our good customers, with large mouth piece rings and 16 in. forged nozzles welded into the shell. This now opens the way to more extensive manufacture of equipment heretofore hammer welded or riveted at considerably lower cost than for hammer welded equipment designed for the same service.

We have now going through our plant approximately forty-six oxy-acetylene welded vessels of various kinds and are pleased to state that up to this writing every vessel has given entire satisfaction and leads to our belief that eventually all types of vessels now being riveted will be fusion welded.

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Instruction Manuals

The Educational Committee of the American Welding Society has issued instruction manuals for Arc, Gas, Resistance and Thermit Welding. A few copies of the bound volume of these manuals are still available at $2.50 per copy. Individual courses may be obtained at 50c. per copy. (Resistance course 35c.)

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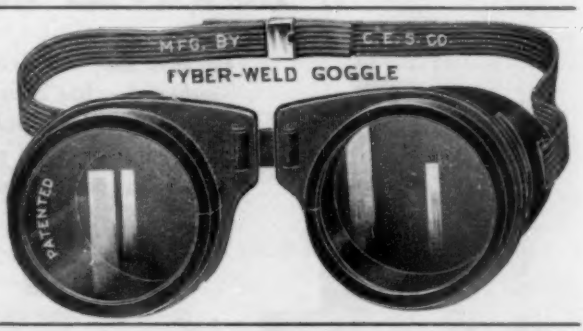

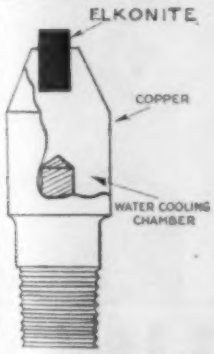

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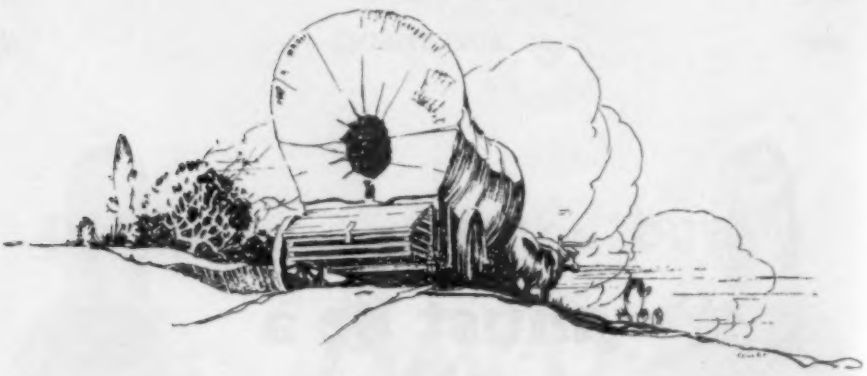

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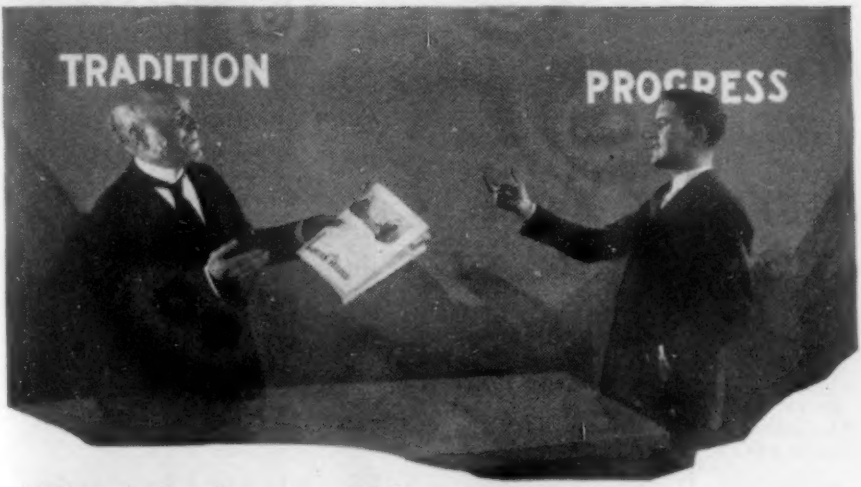

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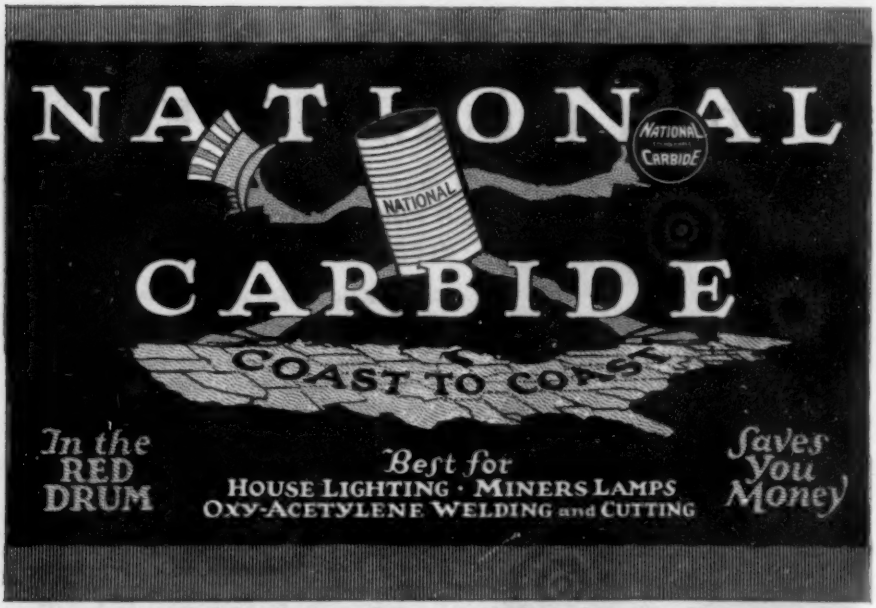

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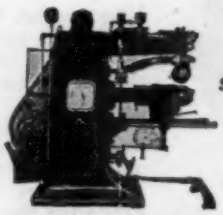
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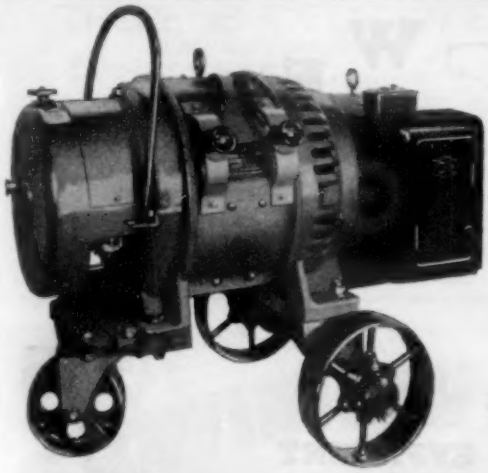

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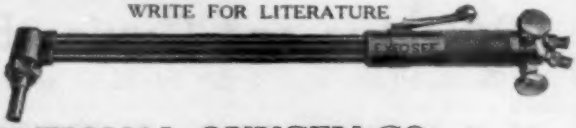

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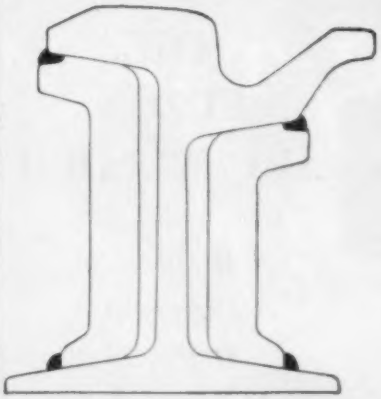

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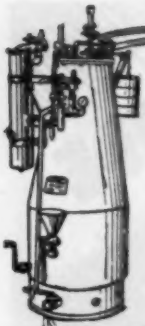

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Name of Company and Address .....

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Applicant is requested to state here length of welding experience and processes involved, also to record any technical or mechanical experience or special interest in the welding field.

References: (1. .....

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QUALIFICATIONS FOR MEMBERSHIP

Extract from By-Laws

ARTICLE I.

Section 1. Individuals having received the approval of a majority of the Membership Committee shall become members of this Society upon the payment of dues, except in the cases of honorary members who shall be elected by unanimous vote of the full Board of Directors.

Section 2. Membership shall be divided into five classes:

Sustaining members, being individuals or individuals delegated by corporations, firms, partnerships, etc., interested in the science and art of welding, with full rights of membership.

Annual dues..... ..... $100.00

Members, being individuals interested in the science and art of welding, with full rights of membership. Engineers or individuals competent by experience or training to plan or direct welding operations are eligible to this class.

Annual dues..... $20.00

Associate members with right to vote but not to hold office, except in Sections as may be provided for by the By-Laws of the Section. Supervising welders, inspectors and skilled operators, with three or more years' practical experience in welding, are also eligible to this class.

Annual dues..... $10.00

Operating members, who are welders or cutters by occupation, without the right to vote or hold office except in Sections as may be provided for by the By-Laws of the Sections.

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